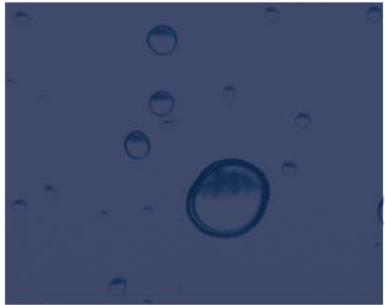The Metropolitan Government of Nashville and Davidson County

Green Infrastructure Master Plan

November 1, 2009

METRO WATER SERVICES

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Metropolitan Government of Nashville and Davidson County
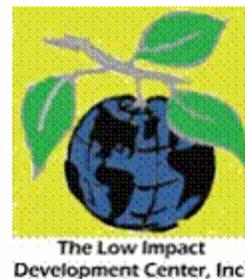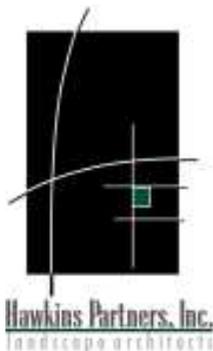# Green Infrastructure Master Plan

Prepared for:

Metropolitan Council
Metropolitan Courthouse
One Public Square
P. O. Box 196300
Nashville, TN. 37219

In Accordance with Ordinance BL2008-345

Prepared by:
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In Conjunction with the AMEC Team:

November 1, 2009
Revision 1 – November 20, 2009

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Green Infrastructure Master Plan
Executive Summary

Directing Ordinance

Ordinance number BL2008-345 amended Title 15 of the Nashville Metropolitan Code and created a stormwater planning district conterminous with the combine sewer system (CSS) area and directed Metro Water Services (MWS), in cooperation with the Metropolitan Planning Department, the Metropolitan Development and Housing Agency, and the Department of Public Works, to be responsible to develop a "plan for the installation of Green Infrastructure (GI) within the Stormwater Master Planning District. Such plan for a Stormwater Master Planning District should include general location and type of installation and its estimated impact on the CSS." The plan also includes a list of infrastructure projects for the next year's capital improvement plan, including maintenance costs and estimated impact on the CSS.

Green Infrastructure

Green Infrastructure (figure right) refers to a kind of stormwater management practice that provides social, economic, and environmental benefits through environmental site design that is intended to mimic the natural hydrologic condition and allow stormwater to infiltrate into the ground, be used for other purposes and evapotranspirate into the air. GI is an ecosystem-based approach that is used to replicate a site's pre-development hydrologic function.

The goal of GI is to design a built environment that remains a functioning part of an ecosystem rather than existing apart from it. This is an innovative approach to urban stormwater management that strategically integrates stormwater controls throughout the urban landscape and does not rely solely on conventional end-of-pipe structural techniques.

This Document

This document has been developed in response to this ordinance. It contains the following sections:

- **Green Infrastructure Practice** – Overview of Green Infrastructure and descriptions of various practices.
- **Technical Analysis of Green Infrastructure** – Analysis of the CSS area with respect to green roofs, three kinds of infiltration practices, tree planting, and rainfall harvesting (cisterns and rain barrels) and its potential impacts on the CSS.

- **Green Infrastructure Projects** – Brief overview of the preliminary design concepts for six projects.
- **Green Infrastructure Incentives and Financing** – Summary of various potentially applicable incentive practices that have been applied in other cities to encourage the use of Green Infrastructure.

Green Infrastructure Practice

Typical GI practices include: downspout disconnection, filter strips, infiltration practices, pocket wetlands, permeable pavement, rain barrels/cisterns, rain gardens/bioretention (figure right – Hill Center, Belle Meade), soil amendments, street trees and afforestation, tree box filters, vegetated (green) roofs, vegetated swales, and assorted other practices.

Each practice has its advantages and drawbacks. This section assesses these and describes each practice in terms of: suitability, limitations, land area demands, relative costs, and maintenance.

Technical Analysis of Green Infrastructure

This section looks, in detail, at the land use characteristics of the CSS area and performs an analysis of the individual and, where applicable, large scale potential impacts of the employment of GI throughout the CSS area. The CSS area was divided into ten sub-basins comprising 7,878 acres of which 45.6% is impervious surfaces (surfaces that do not infiltrate rain water). Detailed analysis of Nashville rainfall was done. This data was used in continuous simulation models to estimate the potential effectiveness of various practices in infiltrating, evapotranspiring, and harvesting rainfall runoff.

The following practices were assessed in detail:

- Rainfall Harvesting (including Rain Barrels)
- Green Roofs
- Urban Trees
- Bioinfiltration Areas, Permeable Surfaces and Tree Planters

The following are key findings from this analysis:

Rainfall Harvesting – There are about 1,300 acres of rooftop in the CSS area generating 1.36 billion gallons of runoff per year. Capturing 80% of all runoff from CSS area rooftops would require 62.3 million gallons of storage.

Rooftops in Nashville generate, on average, about 65.5 gallons per day per 1,000 square feet of rooftop. A 600 gallon cistern sized to use water at a rate equal to the average rainfall can capture about 72% of all rainfall on the rooftop. The standard MWS rain barrel set to empty within 48 hours of filling can capture about 18% of all rainfall on the rooftop. A rainfall harvesting tool was developed.

<u>Green Roofs</u> - There are a total of 708 buildings with flat roofs in the CSS area that could provide 6.8 million square feet of green roof area. A typical 4" thick green roof can remove at least 55% of all rainfall from running off, or 26.3 inches of rainfall annually. If all these buildings were used for green roofs they would remove a total of 112 million gallons from the CSS system on an average annual basis. A green roof sizing tool was developed.

<u>Urban Trees</u> - The CSS area has an existing average canopy cover of 19.5% with basins that vary from 0.14% to 33.3%. Detailed GIS analysis shows there are an estimated 51,800 acceptable new tree planting sites adding 811 acres of urban trees and increasing the percent canopy coverage average to 30% (figure right shows yellow bordered circles for new tree sites). Specific details for various kinds of land use and ownership and a planning and analysis tool were developed.

Continuous simulation modeling and experience elsewhere shows that a tree can intercept 7.26% of the annual rainfall falling on it, and transpire another 54.8%. For the typical 30 foot diameter Nashville tree this amounts of 19,800 gallons per year. If all the potential trees were planted the volume removal would amount to an estimated 660 million gallons annually.

<u>Bioinfiltration Areas, Permeable Surfaces and Tree Planters</u> -
Biofiltration (figure right) describes a garden or landscaped area filled with soil media that can store rainfall runoff for later infiltration and evapotranspiration.

Properly designed, assuming typical soil conditions, and with a 10:1 impervious to pervious surface area ratio, bioinfiltration can remove more than 80% of the runoff from a parking lot on an annual basis. There are 1175 acres of parking in the CSS area generating more than 1,500 million gallons/year. Biofiltration and permeable pavers can remove more than 80% of this amount.

At lower parking lot to surface area ratios or deeper media layers tree planter boxes can also attain better than 80% removal. Design curves for quick sizing were developed based on hourly continuous simulation modeling across a range of impervious to pervious ratios, media depths, and parent soil infiltration rates.

Green Infrastructure Projects

Approximately 50 existing Green Infrastructure sites were identified in and near the downtown area of Nashville. This list was processed for easy access and a database created. To identify potential sites for future and demonstration Green Infrastructure projects interviews were conducted with the Metro Planning Department, Metro Water Services, Metro Public Works, and the Metropolitan Development and Housing Agency. Each department provided their current

problem areas and potentials within the CSS.

A set of design objectives were developed and a large number of projects were screened. This resulted in six project locations for 2010. For each of these locations a preliminary design was completed. The final list of projects is:

- **West Eastland Ave.** – constructed wetland, water quality swales and green roof.
- **Hume Fogg School** – irrigation and grey water harvesting and green roof.
- **Nashville Farmer's Market** - irrigation and grey water harvesting, permeable pavement and tree planting.
- **Parthenon Towers** – bioretention, permeable pavement, and tree planting (shown below 1 = green roof, 2 = bioswale, 3 = pervious concrete).
- **Metro Parks Administrative Facility** - irrigation and grey water harvesting, bioretention, permeable pavement and tree planting.
- **Sheriff's Office and Public Works Complex** - irrigation water harvesting and green roof.

Green Infrastructure Incentives and Financing

A number of incentives were examined to encourage the use of Green Infrastructure for retrofitting existing developments and incorporating "green" stormwater practices in future developments. From these incentives five (5) were selected for further consideration for implementation in Metro Nashville:

- **Stormwater Fee Discounts** – User fee reductions recognizing the reduced impact of properties that employ Green Infrastructure.
- **Rebates and Installation Financing** - Rebates and installation financing is made available to provide incentives for property owners to implement Green Infrastructure practices on their property. The incentive is typically provided in a special target area and can be in the form of grants, rebates or at discounted costs.
- **Development Incentives** - Development incentives were created for private developers. The incentive could waive or reduce fees, requirements, zoning standards, or steps in the permitting process. To qualify for the incentives, the developer must incorporate sustainable site design and green building practices in accordance to the existing development regulations.

♦ **Grants** - Grants present an effective way to provide financial assistance directly to individuals, property owners, community groups, nonprofit organizations and targeted geographical areas. In many cases, grant funds are used to implement pilot projects, which introduce Green Infrastructure practices at no cost to the user.

♦ **Awards & Recognition Programs** - Awards and recognition programs serve as an excellent marketing tool for Green Infrastructure. It presents a unique opportunity for municipalities and businesses to showcase best management practices, increase public awareness of local projects and celebrate the accomplishments of the award recipients.

Recommendations for Next Steps

The growth of a successful Green Infrastructure program involves physical and institutional components and support systems. It mimics the systems that support a successful stormwater program but with significant differences.

We recommend a six part strategy that includes:

♦ Construction, monitoring, modification and publicizing of Green Infrastructure projects;
♦ Review and modification of departmental policies, regulations, programs and incentives to allow for Green Infrastructure;
♦ Modification of design criteria, standards and specifications to incorporate Green Infrastructure options;
♦ Conceptualization and initiation of individual practice programs such as green roofs, urban trees and rainwater harvesting;
♦ Support of public and stakeholder education programs; and
♦ Exploration and initiation of pilot public-private partnership programs.

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1.   Introduction

1.1   Purpose and Scope of Study

1.1.1   Study Purpose

Substitute ordinance BL2008-345 was passed on third reading by the Metropolitan Council on February 3, 2009. The ordinance is included herein as Attachment 1. Among other things, the ordinance created a Stormwater Master Planning District coincident with the service area of the combined sewer system (CSS).

The ordinance directed Metro Water Services to develop a plan for the installation of green infrastructure within the Stormwater Master Planning District through cooperation with the Metropolitan Planning Department, the Metropolitan Development and Housing Agency, and the Department of Public Works. The ordinance specified that the plan, termed the Green Infrastructure Master Plan, include general location and type of installation and its estimated impact on the CSS. Further, the plan is to be updated annually.

> **Ordinance BL2008-345:**
>
> ✓ Established a Stormwater Master Planning District coincident with the CSS area.
> ✓ Directed MWS to develop a Green Infrastructure Master Plan for the Stormwater Master Planning District.
> ✓ Specified that the Master Plan include general location and type of installation and its estimated impact on the CSS.
> ✓ Directed MWS to put forth a list of green infrastructure projects annually for inclusion as part of the capital spending plan.
> ✓ Authorized MWS to promulgate and enforce rules and regulations for the implementation of green infrastructure techniques.

1.1.2   Study Approach

A general depiction of the approach used to develop the Master Plan is presented in Figure 1.1. The study approach contained three primary components, or tracks:

- **Technical Analyses.** Data collection and analyses were performed to ultimately determine the green infrastructure measures best suited for use within the CSS and the potential impacts that the measures could have on inflow to the CSS.
- **Incentives and Financing.** Research was conducted to document communities that effectively implement green infrastructure programs including incentives used by communities to encourage the use of green infrastructure techniques.
- **Project Selection and Design.** Twenty (20) potential green infrastructure projects were identified for possible implementation. Projects were prioritized and conceptual designs were developed for six (6) projects including opinions of probable cost.

The results of the study are discussed in detail in Sections 2 and 3 (Technical Analyses), Section 4 (Project Selection and Design), and Section 5 (Incentives and Financing).
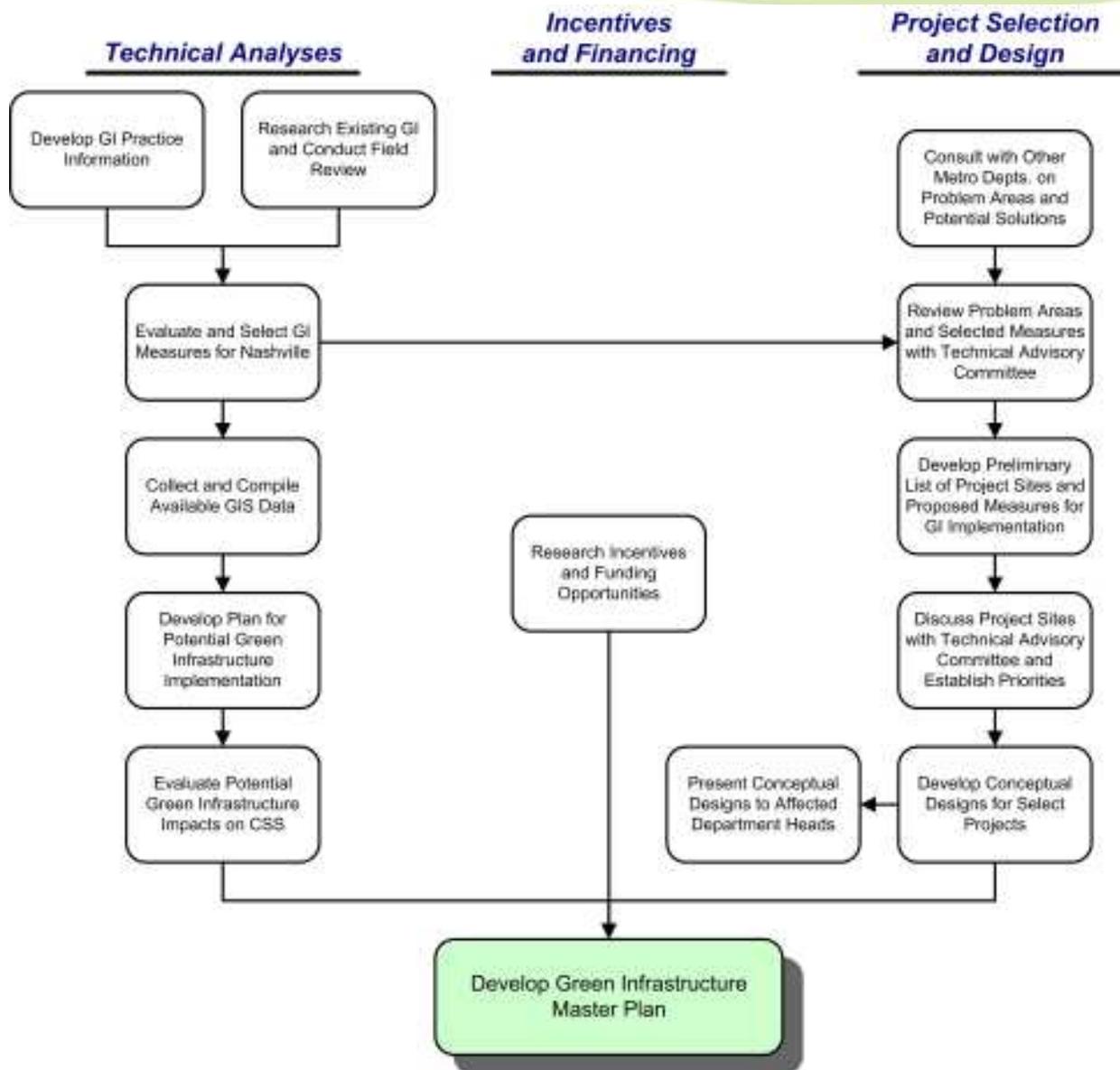
Figure 1.1—Study Approach for Master Plan Development.

1.2   Stormwater Master Planning District

1.2.1   Location and Definition

Substitute Ordinance BL2008-345 defines the Stormwater Master Planning District as the service area for the combined sewer system (CSS). The CSS boundary, and therefore the boundary for the Stormwater Master Planning District, is presented in Figure 1-2.

The District encompasses 7,878 acres (12.31 mi^2). The District is divided into ten (10) sub-basin areas of varying size from 22 acres to 3,388 acres. The District is bisected by the Cumberland River. West of the Cumberland River, the District includes six (6) sub-basins with a

total area of 4,987 acres (7.79 mi^2). East of the Cumberland River, the District includes four (4) sub-basins with a total area of 2,891 acres (4.52 mi^2).

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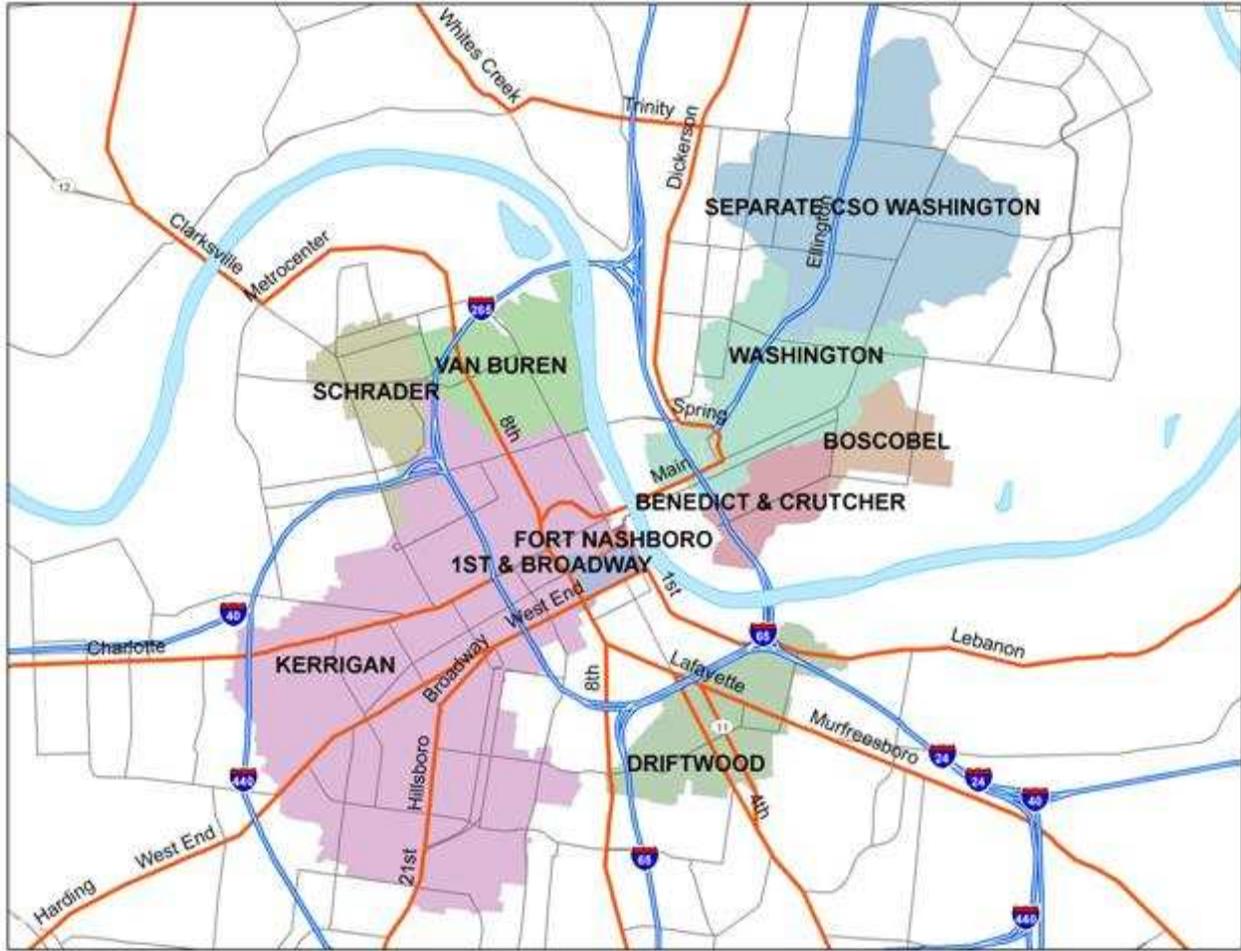
Figure 1.2—Stormwater Master Planning District Boundaries

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2   Green Infrastructure

This section provides an overview of Green Infrastructure and specific practices for the use of Green Infrastructure in site design.

2.1   Green Infrastructure Overview

The term Green Infrastructure (GI) currently has multiple interpretations and definitions depending on the context. For the purpose of this discussion, Green Infrastructure refers to practices that provide social, economic, and environmental benefits through environmental site design that is intended to mimic the natural hydrologic condition and allow stormwater to infiltrate into the ground and evapotranspirate into the air. Green Infrastructure is a natural approach that is used to replicate a site's pre-development hydrologic function. The goal of Green Infrastructure is to design a built environment that remains a functioning part of an ecosystem rather than existing apart from it (Figure 2.1). This is a relatively new approach to urban stormwater management that strategically integrates stormwater controls throughout the urban landscape and does not rely on conventional end-of-pipe structural techniques. Typical benefits of Green Infrastructure include:

> **Defining Green Infrastructure:**
>
> ✓ 19th Century
>   - Frederick Law Olmstead (Father of Landscape Architecture) – Parks and green spaces should be linked/connected rather than isolated.
> ✓ 1999
>   - Green infrastructure recommended as strategy for sustainable community investment that "could make a substantial difference."
> ✓ 2006
>   - McMahon & Benedict – Defined green infrastructure as "an interconnected network of green space that conserves natural ecosystems values and functions and provides assorted benefits to human populations."
>
> C.E. Little. 1990. *Greenways for America*.
>
> President's Council on Sustainable Development. 1999. *Towards a Sustainable America: Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century*.
>
> E.T. McMahon & M.A. Benedict. 2006. *Green Infrastructure: Linking Landscapes and Communities*.

Social Benefits:
- Vegetation and shading reduce urban air temperature
- Provides "Green Job" opportunities
- Educational through street kiosks
- Crime reduction
- Improved health through improved air quality

Economic Benefits:
- Energy cost reduction and water conservation
- "Green Enterprise" business opportunities

Environmental Benefits:
- Carbon sequestration
- Improved water quality
- Carbon footprint reduction
- Recycling and beneficial reuse

Figure 2.1--Functional Landscape.
Source: LID Center

2.2   Green Infrastructure Practices

Part of Nashville's ability to meet the challenge of balancing growth and environmental protection is through incorporating Green Infrastructure into both new and redevelopment efforts. Investing in Green Infrastructure offers the opportunity to enhance the existing infrastructure and protect the environment while simultaneously creating new green jobs, creating demand for green technologies, and revitalizing local neighborhoods.

Green Infrastructure controls are designed to meet multiple stormwater management objectives, including reduction in runoff volume, peak flow rate reduction, and water quality protection (Table 2.1). Multiple small, localized controls are combined into a "treatment train" to provide comprehensive stormwater management. They are designed to integrate into many common urban land uses on both public and private property (Table 2.2). They can be constructed individually or as part of larger construction projects. Decentralized management strategies can be tailored to individual sites, and can eliminate or reduce the need for large-scale, capital-intensive centralized controls, and can reduce the number of combined sewer overflows occurring in a watershed.

This section describes twelve of the most common Green Infrastructure practices. Fact sheets for each of the practices provide a brief introduction to the practice, details on performance, suitability, limitations, cost, and maintenance requirements. It should be noted that cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when designing Green Infrastructure projects.

The following Green Infrastructure practices are included:

1. Downspout Disconnection
2. Filter Strips
3. Infiltration Practices
4. Pocket Wetlands
5. Permeable Pavement
6. Rain Barrels/Cisterns
7. Rain Gardens/Bioretention
8. Soil Amendments
9. Street Trees and Afforestation
10. Tree Box Filters
11. Vegetated Roofs
12. Vegetated Swales

Table 2.1--Effectiveness of GI Practices in Meeting Stormwater Management Objectives.

Practices	Volume	Peak Discharge	Water Quality
Downspout Disconnection	◉	◉	◉
Filter Strips	○	○	◉
Infiltration Practices	◉	○	◉
Pocket Wetlands	●	●	●
Permeable Pavement	●	●	◉
Rain Barrels / Cisterns*	◉	○	○
Rain Gardens	●	●	●
Soil Amendments	◉	◉	◉
Street Trees and Afforestation	◉/●	○/●	○/●
Tree Box Filters	◉	◉	●
Vegetated Roofs	◉	●	●
Vegetated Swales	◉	◉	●

* A single cistern typically provides greater volume reduction than a single rain barrel.

Key: ● High effectiveness ◉ Medium effectiveness ○ Low effectiveness

Rankings are qualitative. "High effectiveness" means that one of the GI practice's primary functions is to meet the objective. "Medium effectiveness" means that a GI Practice can partially meet the objective but should be used in conjunction with other GI practices. "Low effectiveness" means that the GI practice's contribution to the objective is a byproduct of its other functions, and another decentralized control should be used if that objective is important.

Table 2.2--Green Infrastructure Land Use and Land Area Selection Matrix.

Practices	Criteria						Land Area Required
	Land Use						
	Schools	Com.	Indust.	SF Res.	MF Res.	Parks / Open Space	
Disconnected Downspout	●	◉		●	●	●	○
Filter Strips	●	●	◉	◉	●	●	◉
Infiltration Practices	●	●	●		◉		○
Pocket Wetlands		●	◉		◉	●	●
Permeable Pavement	●	●	◉	●	●	●	○
Rain Barrels / Cisterns	●	◉	◉	●	●		○
Rain Gardens	●	●		●	●	●	◉
Soil Amendments	◉	◉		◉	◉	●	○
Street Trees and Afforestation	◉	○	◉	●	◉	●	○/●
Tree Box Filters	◉	●			●	●	○
Vegetated Roofs	●	●	●		●		○
Vegetated Swales	●	●	●		●		◉

● - Well suited for land use applications or high relative dedicated land area required.
◉ - Average suitability for land use applications or moderate relative dedicated land area required.
○ - Low relative dedicated land area required.
Blank – Not generally applicable for land use.

2.3   Downspout Disconnection

Downspout disconnection is the process of separating roof downspouts from the sewer system and redirecting roof runoff onto pervious surfaces, most commonly a lawn. This gives the roof runoff the opportunity to infiltrate, reducing the volume of runoff that must be captured by additional GI practices, or runoff into the public stormwater system. Reducing the amount of directly connected impervious area decreases the peak discharge rate by increasing the amount of time it takes runoff to flow over the site. Water quality improvements come from the infiltration of roof runoff, and the reduction in CSOs resulting from runoff volume reduction.

Benefits:

✓   Reduced runoff volume
✓   Reduced peak flow rate
✓   Improved water quality

Suitable Locations

⬥   Downspouts adjacent to landscaped areas
⬥   Downspouts adjacent to lawns
⬥   Downspouts adjacent to permeable pavement

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	◉
Water Quality – overall	◉
Sediment	◉
Nutrients	◉
Metals	◉
Oil and Grease	◉

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

Downspouts must discharge into a suitable receiving area, such as a lawn, garden, landscaped area, rain garden, rain barrel, or infiltration practice. Runoff must not flow toward building foundations or onto adjacent property. Improper installation may lead to basement flooding.

Impediments to Implementation

⬥   Plumber may be required to disconnect sump pump.
⬥   Some municipal codes outlaw this practice.

Land Area Demands

Downspout disconnection itself does not require any additional land area; however, runoff must be directed to a properly sized GI Practice or other pervious surface, such as a lawn or landscaped area.

Land use	Suitability
Schools	●
Commercial	◉
Industrial	
Single-Family Residential	●
Multi-Family Residential	●
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

💧 < $100 per disconnection

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

💧 Check downspouts periodically for clogs or signs of erosion.

Downspout Disconnection into Vegetated Area
Source: LID Center

2.4 Filter Strips

Filter strips are uniformly sloped areas of dense vegetation that act as a buffer often used to provide providing water quality pretreatment to runoff flowing from its source to another GI Practice. Water quality improvements are accomplished through infiltration and vegetative filtering of sediments, organic matter, nutrients, and pesticides. Treatment effectiveness

Benefits:

✓ Reduced peak discharge rate
✓ Reduced TSS
✓ Reduced pollutant loading
✓ Enhanced site aesthetics

depends on dense vegetation and sufficient contact time. Filter strips are not designed to provide storage of large runoff volumes, but can significantly reduce the volume of runoff from small, frequently-occurring storms if the soils are sufficiently pervious. Filter strips increase surface roughness, reducing runoff velocity and thereby decreasing peak discharge rates.

Suitable Locations
- Alongside rain gardens
- Alongside permeable pavement
- At the base of roof downspouts
- Along roadside shoulders

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	○
Peak Flow Rate Reduction	○
Water Quality	◉
Sediment	●
Nutrients	◉
Metals	◉
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   ○ - Low effectiveness

Limitations
- May not be appropriate for industrial sites or locations where spills may occur.
- Require a thick vegetative cover in order to function properly.
- Filter length must be adequate and flow characteristics acceptable or water quality performance can be severely limited.
- Not suitable for slopes less than 1% or greater than 15%.
- Supplemental irrigation may be required during initial plant establishment and prolonged drought conditions.

Impediments to Implementation
- Generally well accepted

Land Area Demands
Require a large land area compared to other Green Infrastructure GI practices. This area can be incorporated into roadway shoulders or other turf areas.

Land use	Suitability
Schools	●
Commercial	●
Industrial	◉
Single-Family Residential	◉
Multi-Family Residential	●
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

💧 < $1 per square foot

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

💧 Mow regularly.
💧 Inspect twice annually for signs of erosion or vegetation damage.
💧 Periodically remove accumulated trash and debris.

Filter Strip
Source: www.trinkausengineering.com

2.5   Infiltration Practices

Infiltration practices are GI practices, such as infiltration trenches and dry wells, that enhance water percolation through a media matrix that slows and partially holds stormwater runoff, facilitating pollutant removal. Infiltration trenches are excavated 3 to 12 feet deep, lined with filter fabric, and filled with stone, allowing stormwater runoff to infiltrate into surrounding soils through the trench's bottom and sides. Dry wells are pits filled with gravel or stone aggregate and are designed to catch stormwater from roof downspouts or paved areas. Water quality is improved through filtering by the media and surrounding soils, allowing these infiltration techniques to remove a variety of pollutants.

Benefits:

✓   Reduced stormwater volume
✓   Reduced pollutant loading
✓   Increased groundwater recharge

Suitable Locations
- Intensively developed areas
- At the base of roof downspouts
- Dry wells can be used on steep slopes
- Hydrologic Soil Group (HSG) A and B soils

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	○
Water Quality	◉
Sediment	●
Nutrients	◉
Metals	●
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations
- Infiltration trench designs must include filter strips or other filtering mechanisms to prevent sediment from reaching and clogging the trench.
- Dry wells should not be installed in areas of high sediment loading.
- High failure rate if soil and subsurface are not sufficiently permeable.
- Not appropriate for industrial sites or locations where spills may occur.
- Risk of groundwater contamination in soils with very high infiltration rates.

Impediments to Implementation
- High risk of failure due to improper soil conditions or excessive sediment inputs.
- Potential concerns over groundwater contamination.

Land Area Demands
Consume 2-3% of their drainage areas. Can be constructed as thin strips in narrow areas, and can therefore often be constructed in otherwise unusable areas.

Land use	Suitability
Schools	●
Commercial	●
Industrial	●
Single-Family Residential	
Multi-Family Residential	◉
Parks/Open Space	

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

⬩ $5 per ft^3 of stormwater treated

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

⬩ Periodically remove any accumulated trash or debris.
⬩ Inspect annually for signs of impaired infiltration (sediment accumulation, ponding).
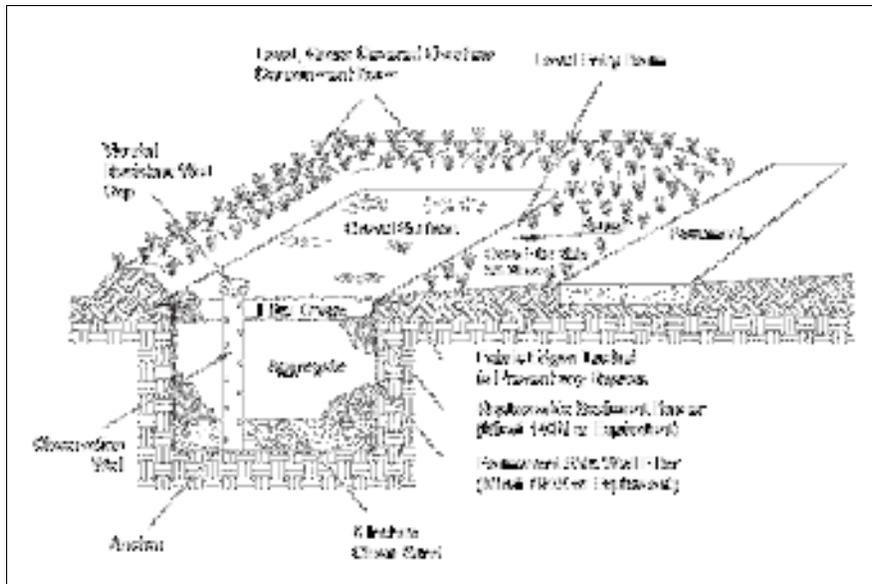
Infiltration Trench Schematic
Source: Northern Virginia GI Practice Handbook

2.6   Pocket Wetlands

Pocket wetlands are shallow marsh-like systems constructed to control stormwater volume and remove pollutants for drainage areas of 5 to 10 acres. Because they are engineered structures, pocket wetlands have less biodiversity than natural wetlands yet still provide robust pollutant removal and habitat value. Pollutant removal in these systems occurs through settling, microbial biodegradation, and uptake by vegetation. By increasing the duration of discharge and controlling stormwater volume, pocket wetlands are able to significantly reduce peak discharge.

Benefits:

✓   Reduced peak discharge rate
✓   Reduced TSS
✓   Reduced pollutant loading
✓   Enhanced site aesthetics

Suitable Locations

- Low permeability soils
- Flat topography

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	●
Peak Flow Rate Reduction	●
Water Quality	●
Sediment	●
Nutrients	◉
Metals	◉
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

- Require knowledgeable management for successful operation.
- Mosquito breeding is likely, however mosquito predators will also be present.
- Not suitable for steep or unstable slopes.
- Base flow or supplemental water may be required during dry periods.

Impediments to Implementation

- Concerns about mosquito breeding
- Safety concerns related to standing water when constructed where there is public access

Land Area Demands

Pocket wetlands require a relatively large, dedicated area, typically 4-6% of the drainage area. They should be located in isolated areas where public access can be restricted.

Land use	Suitability
Schools	
Commercial	●
Industrial	◉
Single-Family Residential	
Multi-Family Residential	◉
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

♦ $1.50 per ft^3 of stormwater treated

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

♦ Inspect twice per year for burrows, sediment accumulation, structural integrity of the outlet, and litter accumulation.
♦ Periodically remove accumulated trash and debris.
♦ Where permitted, stock regularly with mosquito fish (*Gambusia spp.*) to enhance natural mosquito control.
♦ Harvest vegetation annually.
♦ Remove accumulated sediment in forebay every 5-7 years.

2.7   Permeable Pavement

Permeable pavement allows stormwater to pass through voids in the paved surface and infiltrate into the sub-base. Permeable pavements may be constructed of four basic material types: porous asphalt; porous concrete; interlocking paver blocks; and plastic grid. Permeable pavements may be designed to exfiltrate captured runoff into the subsoil, discharge stored runoff into existing storm drains, or store runoff for use in irrigation. The amount of exfiltration depends on the permeability of the existing soil. Permeable pavements simultaneously serve as hardscape and as stormwater infrastructure, and are therefore especially practicable where space constraints preclude the use of other water quality GI practices.

Benefits:

✓ Reduced runoff volume
✓ Reduced peak discharge rate
✓ TSS
✓ Reduced pollutant loading
✓ Reduced runoff temperature
✓ Groundwater recharge (if soils are sufficiently permeable and no underdrain is placed underneath)
✓ Reduced heat island effect
✓ Dual purpose

Suitable Locations

♦ High permeability soils where exfiltration is desired
♦ Parking lots
♦ Driveways
♦ Low-traffic roadways
♦ Footpaths

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	●
Peak Flow Rate Reduction	●
Water Quality	◉
Sediment	●
Nutrients	◉
Metals	◉
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

♦ Care must be taken to prevent excessive deposition of sediment onto the pavement, which can clog voids and decrease the pavement's infiltration performance.
♦ Not suitable for areas where hazardous materials are loaded, unloaded, or stored or where there is a potential for truck spills and fuel leak accidents.
♦ Not suitable for slopes greater than 5%. For slopes greater than 2 or 3%, the sub-base should be terraced.
♦ Paver designs with large spacings may not be ADA compliant.

Impediments to Implementation

♦ Widespread belief that porous pavement systems are difficult to maintain and prone to failure.

Land Area Demands

Does not require dedicated land area.

Land use	Suitability
Schools	●
Commercial	●
Industrial	◉
Single-Family Residential	●
Multi-Family Residential	●
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

💧 $5-15 per square foot

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

💧 Annual or semi-annual vacuuming is required to maintain the permeability of the pavement surface.
💧 Maintain planted areas adjacent to pavement.
💧 Immediately clean soil deposited on pavement.
💧 Do not allow construction staging, soil/mulch storage, etc. on unprotected pavement surface.
💧 Clean inlets draining to the subsurface bed twice per year. Inspect pavement annually for signs of damage.
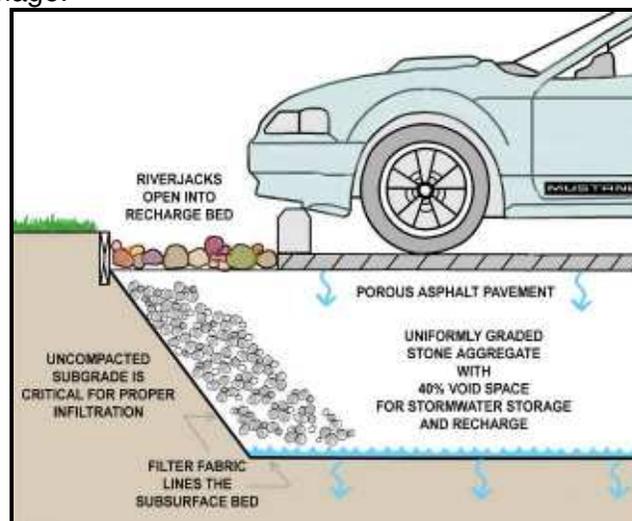
Permeable Pavement Cross-section
Source: Cahill Associates

2.8 Rain Barrels / Cisterns

Rain barrels and cisterns store rooftop runoff. The stored water is a source of untreated 'soft water', free of most sediment and dissolved salts and ideal for later reuse in lawn and garden watering. Rain barrels are most often used for private residences while cisterns are typically larger, can be stored above or below ground, and have both residential and commercial applications. Rain barrels and cisterns can effectively reduce runoff volumes for very small storms. An initial

Benefits:

✓ Reduced runoff volume
✓ Reduced peak discharge rate
✓ Reduced TSS
✓ Reduced pollutant loading
✓ Reduced potable water demand

runoff volume is retained by the storage devices, ranging from approximately 50 gallons to many thousand for each device, prior to the remaining runoff bypassing the systems. Modest water quality improvements will be gained by using rain barrels and cisterns to reduce the volume of stormwater available to convey pollutants.

Suitable Locations

⬥ Connected to roof downspouts
⬥ Cisterns – beneath buildings or paved areas

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	○
Water Quality – Overall	○
Sediment	◉
Nutrients	○
Metals	○
Oil and Grease	○

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

⬥ Normally sized to capture only small storms. Must be used in conjunction with supplemental GI practices to capture larger flows.
⬥ Suitable for capture only of relatively unpolluted runoff, such as that from rooftops.
⬥ Must be emptied between storms for proper functioning.

Impediments to Implementation

⬥ Cost per gallon stored.

Land Area Demands

Land area required is minimal. Rain barrels are generally sized to store about 50 gallons of runoff, occupying approximately four square feet of land area. Cisterns are generally much larger, are often vertical in construction, but can be constructed below ground, and therefore require no dedicated land area.

Land use	Suitability
Schools	●
Commercial	◉
Industrial	◉
Single-Family Residential	●
Multi-Family Residential	●
Parks/Open Space	

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

- 💧 $1 per gallon of stormwater stored

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

- 💧 Rain barrels and cisterns must be emptied between storm events.
- 💧 Inspect regularly for clogs and leakage.
- 💧 Flush annually to remove accumulated sediment.

Rainwater Cistern
Source: Craven County, NC

2.9 Bioinfiltration/Rain Gardens / Bioretention

Bioinfiltration cells, also known as bioretention or rain gardens, are vegetated depressions that store and infiltrate runoff from impervious surfaces, such as roofs and pavement. Bioretention and rain gardens generally work through filtration of the runoff into a collection system.

An engineered soil medium maximizes infiltration and pollutant removal. Uptake by plants reduces runoff volume and pollutant concentrations. Bioinfiltration is typically designed to drain within 24-48 hours. Bioinfiltration is suitable for use in a wide range of land uses, from residential to commercial, industrial, and ultra-urban settings. Use of Bioinfiltration for stormwater management is ideal for median strips, parking lot islands, and swales. Bioinfiltration provides storage and exfiltration capacity to surrounding soils, as well as plant uptake and evapotranspiration. Bioinfiltration is among the best GI practices for stormwater quality control, taking advantage of both physical and biological removal pathways.

> **Benefits:**
>
> ✓ Reduced runoff volume
> ✓ Reduced peak discharge rate
> ✓ Reduced pollutant loading
> ✓ Reduced runoff temperature
> ✓ Groundwater recharge (if soils are sufficiently permeable and no underdrain is placed underneath)
> ✓ Habitat creation
> ✓ Enhanced site aesthetics
> ✓ Reduced heat island effect

Suitable Locations

- ⬥ Landscaped areas
- ⬥ Parking lot islands
- ⬥ Median strips
- ⬥ Adjacent to roof downspouts
- ⬥ Residential lawns

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	●
Peak Flow Rate Reduction	●
Water Quality	●
Sediment	●
Nutrients	◉
Metals	●
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

In areas with low permeability soils, bioinfiltration cannot be used for infiltration, and must be fitted with underdrains connected to the storm drainage system. Bioinfiltration should not be used where slopes are greater than 20%, or where the depth to the water table is less than two feet. In cases of "hot spot" pollutant generation (e.g., gas stations), an impermeable liner may be required. In areas with high sediment loads, pretreatment with filter strips or settling basins is necessary to avoid clogging.

Impediments to Implementation

- Lack of support from municipal DOTs due to absence of bioretention specifications and standards in regulations.
- Limited data on existing implementation of bioinfiltration cells.
- Requires identification of plants suitable for the region.

Land Area Demands

Bioinfiltration can usually be planned or retrofitted into landscaped areas, and require a moderate amount of land area, up to 5% of the drainage area, or more if drainage area is 100% impervious.

Land use	Suitability
Schools	●
Commercial	●
Industrial	
Single-Family Residential	●
Multi-Family Residential	●
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

- $3-4 per square foot for simple residential designs
- $10-40 per square foot for more complex commercial applications

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

- May require irrigation during initial vegetation establishment.
- Requires periodic weeding, pruning and trash removal, annual mulch replenishment.
- Inspect semi-annually for sediment buildup and/or erosion.

Bioinfiltration
Source: LID Center

2.10 Soil Amendments

Soil amendments are any materials, organic or inorganic, that are added to a soil to increase its physical properties and enhance plant growth. Soil amendments increase a soil's infiltration and water retention capacity and thereby add storage volume to a site. The maximum stormwater flow rate is reduced by the enhanced infiltration capability of the site and the additional storage volume that is realized in the amended soils. Amended soils have the ability to remove pollutants through sorption, precipitation, filtering, and bacterial and chemical degradation.

Benefits:

- ✓ Reduced runoff volume
- ✓ Reduced peak discharge rate
- ✓ Reduced pollutant loading
- ✓ Reduced runoff temperature
- ✓ Groundwater recharge (if soils are sufficiently permeable and no underdrain is placed underneath)
- ✓ Habitat creation
- ✓ Enhanced site aesthetics
- ✓ Reduced heat island effect

Suitable Locations

- 💧 Landscaped areas
- 💧 Turf
- 💧 Residential lawns

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	◉
Water Quality	◉
Sediment	●
Nutrients	◉
Metals	●
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

- 💧 Soil amendments can be applied to any turf or landscaped areas.
- 💧 Soil amendments are most easily applied during construction as a last step prior to planting.

Impediments to Implementation

- 💧 Additional cost to obtain and apply soil amendments

Land Area Demands

This practice involves amending soils used for landscaping or turf, and does not require dedicated land area.

Land use	Suitability
Schools	◉
Commercial	◉
Industrial	
Single-Family Residential	◉
Multi-Family Residential	◉
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

♦ < $1 per square foot

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

♦ Prevent soil compaction by posting signage prohibiting use of heavy equipment on amended soils.

Soil Amending Process
Source: U.S. EPA

2.11 Street Trees and Afforestation

Planting of individual street trees and afforestation of larger disturbed areas can have a significant impact on stormwater runoff. Trees reduce runoff volume through evapotranspiration and interception (capture and storage of rainfall on leaf surfaces). They also improve the infiltration capacity of the soil, reducing runoff potential. Planting individual trees will reduce volume from small, frequent storm

Benefits:

- ✓ Reduced runoff volume
- ✓ Reduced peak discharge rate
- ✓ Reduced phosphorus loads

events, but will not appreciably affect large storms. Afforestation of an entire area, however, can have a dramatic effect on soil permeability. An area replanted and allowed to grow into a mature stand of trees with little or no clearing of undergrowth can have a much higher infiltration rate than other land uses. Trees may be planted as seeds, seedlings, or semi-mature trees.

Suitable Locations

- ⬧ Flow paths
- ⬧ Depressions
- ⬧ Vegetated areas
- ⬧ Roadway medians and shoulders
- ⬧ Alongside (and a suitable distance away from) sidewalks and walkways

Stormwater Management Objective	Treatment Effectiveness Street Trees / Afforestation
Volume Reduction	◉/●
Peak Flow Rate Reduction	○/●
Water Quality	○/●
Sediment	○/●
Nutrients	○/●
Metals	○/●
Oil and Grease	○/●

● - High effectiveness   ◉ - Medium effectiveness   ○ - Low effectiveness

Limitations

- ⬧ Root and trunk support structures may be required.
- ⬧ Native trees are preferred.
- ⬧ Select sites that allow for growth (root zone and canopy).
- ⬧ Soil compaction should be avoided. Soil amendments can be used to increase permeability.

Impediments to Implementation

- ⬧ Street trees require regular maintenance, and can experience high mortality in urban areas.
- ⬧ Afforestation requires dedicated areas that will experience only minimal soil disturbance. They are not well suited to high-traffic areas.

Land Area Demands

Street trees require room for root and canopy growth. Afforestation requires large dedicated areas.

Land use	Suitability
Schools	●
Commercial	●
Industrial	
Single-Family Residential	●
Multi-Family Residential	●
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

◆ Tree seedlings range from $6 to $25 each, depending on size

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

◆ Check for interference with utility lines.
◆ Check for root interference of paved areas.
◆ Remove dead or diseased limbs.
◆ Prune as necessary.
◆ Protect from invasive species.
◆ Provide supplemental irrigation during initial establishment.

2.12 Tree Box Filters

Tree box filters are mini filtration areas beneath trees in in-ground containers, typically installed in urban areas. An efficient use of land, the surface appearance of a tree box is a tree or shrub in a tree grate along a curb. The vegetation sits in a concrete box of bioretention media through which street or parking lot runoff is filtered prior to discharge into the

Benefits:
✓   Reduced TSS
✓   Reduced pollutant loading
✓   Reduced urban heat island effect

storm drain system. For low to moderate flows, stormwater enters through the tree box's inlet, filters through the soil, and exits through an underdrain into the storm drain. For high flows, stormwater bypasses the tree box filter if it is full and flows directly to the downstream curb inlet. A single tree box can store 100-300 gallons of stormwater; therefore the use of multiple devices is required to achieve significant reductions in the volume or peak flow rate of large storms. Tree box filters are based on bioretention technology, with improvements in performance, reliability, pollutant removal, ease of construction, aesthetics, and maintenance costs.

Suitable Locations
- Curbs
- Parking lots
- Walkways

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	◉
Water Quality	●
Sediment	●
Nutrients	◉
Metals	●
Oil and Grease	●

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations
- Tree box filters treat only small storms, and provide minimal volume reduction. Must be used in conjunction with supplemental GI practices for larger storms.

Impediments to Implementation
- Tree box filters are a new technology. Many engineers and builders have little experience with their design or installation.

Land Area Demands
The standard size for a tree box filter is 6'x6', though they can be manufactured in larger and smaller sizes.

Land use	Suitability
Schools	◉
Commercial	●
Industrial	
Single-Family Residential	
Multi-Family Residential	●
Parks/Open Space	●

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

💧 $12,000 - $15,000 per 6'x6' unit

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

💧 Vegetation may require supplemental irrigation during initial plant establishment and during extended drought periods.
💧 Periodically remove accumulated trash and sediment, replenish mulch
💧 Inspect periodically for clogging
💧 Vegetation requires periodic maintenance, including pruning, weeding and fertilization.

Tree box filter

2.13 Vegetated Roofs

Vegetated roofs, also known as green roofs, eco-roofs, or nature roofs, are structural components that capture, filter, and detain rainfall. Vegetated roofs can be constructed over any type of roofing material, providing that the roof itself can handle the weight of the vegetation. The system consists of waterproofing material, growing medium, and vegetation. Most vegetated roofs can be considered "intensive" or "extensive," depending on the type of vegetation used and the roof area's planned usage. Intensive

Benefits:

- ✓ Reduced runoff volume
- ✓ Reduced peak discharge rate
- ✓ Reduced pollutant loading
- ✓ Reduced runoff temperature
- ✓ Enhanced site aesthetics
- ✓ Reduced building energy use
- ✓ Reduced urban heat index

vegetated roofs employ a wide variety of plant species that require deep layers of media and continuous maintenance. This type is generally limited to flat roofs, and often serves as a park-like area accessible to the public. Extensive vegetated roofs have shallow vegetation, usually 4 inches or less, consisting of succulents, grasses, herbs, or mosses. This type of roof requires minimal maintenance, and is generally not open for public access. A major benefit of vegetated roofs is their ability to absorb stormwater and release it slowly over a period of several hours. They help reduce the volume of runoff as well as the amount of pollution entering local drainage systems and, ultimately, receiving waters. In addition, adding vegetation to a roof will provide protection from ultraviolet radiation and extreme temperature fluctuations, two elements that cause standard roof membranes to deteriorate, and reduce urban heat island effects.

Suitable Locations

- ⬧ Intensive – flat roofs
- ⬧ Extensive – roofs with slopes up to 30%

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	●
Water Quality	●
Sediment	
Nutrients	
Metals	
Oil and Grease	

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

- ⬧ Not suitable for steeply sloped roofs.

Impediments to Implementation

- ⬧ Lack of widespread experience
- ⬧ Initial cost

Land Area Demands

None.

Land use	Suitability
Schools	●
Commercial	●
Industrial	●
Single-Family Residential	
Multi-Family Residential	●
Parks/Open Space	

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

- $5-25 per square foot

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

- Irrigate during plant establishment and extended dry periods.
- During the plant establishment period, weeding, fertilization (if needed), and infill planting is recommended every three to four months during plant establishment. Thereafter, only two visits per year for inspection and light weeding should be required.
- Periodically inspect drainage outlets for clogs.
- Periodically inspect waterproof membrane for drainage or leaks.

Seattle City Hall Green Roof
Source: SvR Design Company

2.14 Vegetated Swales

Vegetated swales are broad, shallow channels designed to convey and infiltrate stormwater runoff. The swales are vegetated along the bottom and sides of the channel, with side vegetation at a height greater than the maximum design stormwater volume. Vegetated swales reduce stormwater volume through infiltration, improve water quality through infiltration and vegetative filtering, and reduce runoff velocity by increasing flow path lengths and channel roughness. Reductions in discharge volume will be most apparent in moderate to small storms. Channel vegetation removes large and coarse particulate matter from stormwater.

Benefits:

✓ Reduced stormwater volume
✓ Reduced peak discharge rate
✓ Reduced TSS
✓ Enhanced site aesthetics

Suitable Locations

⬥ Roadway medians
⬥ Rights-of-way
⬥ Property perimeter
⬥ Connect runoff source to storage GI Practice

Stormwater Management Objective	Treatment Effectiveness
Volume Reduction	◉
Peak Flow Rate Reduction	◉
Water Quality	●
Sediment	●
Nutrients	◉
Metals	◉
Oil and Grease	◉

● - High effectiveness   ◉ - Medium effectiveness   O - Low effectiveness

Limitations

⬥ Not be appropriate for industrial sites or locations where spills may occur.
⬥ Require a thick vegetative cover to function properly.
⬥ Not suitable for use on steep slopes.
⬥ Susceptible to erosion when flow velocities are high.

Impediments to Implementation

⬥ Use is prohibited by law in some areas where municipalities require curb and gutter systems.
⬥ Land area requirements exceed underground systems.

Land Area Demands

Can have a relatively large footprint on a site. Best suited for linear vegetated areas that will experience little foot traffic, such as road shoulders.

Land use	Suitability
Schools	●
Commercial	●
Industrial	●
Single-Family Residential	
Multi-Family Residential	●
Parks/Open Space	

● - Well suited for land use applications.
◉ - Average suitability for land use applications.
Blank – Not generally applicable for land use.

Cost

💧 $0.50 per ft^2

Note: Cost estimates are included for informational purposes only. More accurate cost estimates should be obtained when planning Green Infrastructure projects.

Maintenance

💧 Mow and weed regularly.
💧 May require irrigation during prolonged drought.
💧 Promptly repair ruts and reseed bare areas.
💧 Periodically clear debris, accumulated sediment, and other blockages.
💧 Inspect regularly for pools of standing water where mosquitoes can breed.

Vegetated Swale

3   Technical Analysis of Green Infrastructure

This section discusses the analysis of the use of Green Infrastructure (GI) in the combined sewer system area. After an overview section describing the study area and a discussion of factors affecting the use of Green Infrastructure key GI practices are individually assessed.

3.1 Study Area

3.1.1   Study Area Overview

The CSS study area is comprised of ten basin areas of varying size, land uses, needs, and with different flow and overflow characteristics. Example characteristics include:

- The Boscobel, 1st & Broadway, Van Buren, and Benedict & Crutcher basins are seen as having significant frontage on theee Cumberland River and therefore have a greater need to intercept direct discharges.
- Recent modeling under the overflow program showed that the Boscobel and Van Buren basins are the most sensitive to smaller volume reductions and, therefore, may respond most directly to GI initiatives that can be effective in the 1-inch rainfall range.
- In some cases, habitual flooding as well as CSS volume removal could be accomplished or aided by GI initiatives. One such case is along West Eastland Road in the Washington basin.
- Current street or other capital improvement projects may provide opportunities for GI add-ons or modifications to original designs in some places.

Figures 3.1 through 3.3 and corresponding Tables 3.1 through 3.3 show the combined sewer system (CSS) study area, impervious coverage, and soils information, respectively.

Facts About The Study Area:

- ✓ The total CSS area is 12.31 square miles (7,878 acres).
- ✓ Basins range in size from 22 acres to 3,388 acres.
- ✓ The 1st & Broadway and Ft. Nashboro basins have more than 80% impervious areas. The remaining basins have between 30% and 50% impervious areas. The average basin impervious area is 45.6%.
- ✓ Existing impervious areas are split evenly between: building rooftops, roads, and parking areas at about 1,200 acres each.
- ✓ Almost 75% of the CSS area is underlain with type B soil, though urban modification and other unknowns often make this generalization moot.
- ✓ Based on rainfall analysis, on average, 82 gallons per day of rain falls on a one thousand square foot surface in Nashville resulting generally in 65.5 gallons of runoff.
- ✓ The CSS area generates an average of 3.7 million gallons of rooftop runoff per day.

3.1.2 Impervious Cover

From Figure 3.1 and Table 3.1 it can be seen that the CSS basins range in size from 22 acres to 3,388 acres and vary greatly in shape and connectivity to the Cumberland River. The basins also vary greatly in impervious coverage and fall into two distinct categories. For two basins, 1st & Broadway and Ft. Nashboro, over 80% of the total basin area is impervious. For the rest of the basins, between 30% and 50% of the total basin areas are impervious. This implies that there may be different approaches to the implementation of GI.

The total imperviousness across all basins is divided equally between three sources: building rooftops, roads and parking areas. Each source averages between 30% and 36% of the total

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CSS area imperviousness. However, as shown in Table 3.2 the breakdown for each individual basin varies considerably from those averages.

3.1.3 Soils

Figure 3.3 and Table 3.3 show the Natural Resource Conservation Service (NRCS) soil features for the CSS area. As can be seen from the Figure, the predominant soil type underlying the CSS area is hydrologic soil group (HSG) B at almost 75%. Obviously the more the area has been modified by human activity, the more the actual soil characteristics (especially the key characteristics for our study: ability of the soil to both hold water and infiltrate it) are not reflected in the large scale mapping. To test the ability of these NRCS soils to capture rainfall, a continuous simulation of hourly rainfall data from 1971 through 2006 was completed. Table 3.4 shows the results for the four soils groups, as well as for a 100% impervious area.

These results are a water balance simulation, a simple accounting of rainfall onto the soil/vegetation matrix and what happens to it. For this simulation, a combination of forest and grassy meadow was used for the vegetation. The values in Table 3.4 reflect the simulation findings of others for a location with a rainfall distribution similar to that in Nashville. For each soil type the evapotranspiration is roughly equal, the shift coming predominantly in the surface runoff portion as soils change from sandy (soil group A) to clay (soil group D). Note, that on an annual basis even type D soils have a high infiltration percentage – just not on a design storm basis.

3.1.4 Rainfall

In order to assess the potential for rainwater capture to reduce volumes of flow to the CSS, a series of assessments were performed using both hourly and daily rainfall data. Figures 3.4 and 3.5, respectively, show hourly and daily rainfall. Figure 3.6 shows an accumulation plot of daily rainfall totals from January 1948 through August 2009.The hourly plot, with data from 1971 through 2006, although not shown, was very similar in slope. The slope of the daily rainfall plot indicates how fast rainfall accumulates over time, and the average slope provides us an estimate of rain supply – that is volume in time. The slope of the line is 0.1311 – or 0.13 inches of rainfall per day on average.

Using this slope information, on <u>average</u>, a one thousand square foot roof will yield about 82 gallons per day of <u>rainfall</u>.

*0.13 in of rainfall / day * (1 ft / 12 in) * 1000 sq feet = 10.83 cu.ft. = 82 gallons of rainfall/day*

However, rainfall never occurs that evenly spaced in time, as is shown in Figure 3.7 which is a plot of annual rainfall amounts. The blue line is a five-year moving average. So it might be, for example, that the designer finds it cost effective to plan for a dry year versus a wet year in rainfall harvesting; or plan for a wet year or extreme storm event when designing for flood control.

3.1.5   Runoff

The runoff from this rainfall depends on soils, land use and cover, as well as how hard and long it rains. It also depends on the collection and flow system it encounters. GI design attempts to intercept the rainfall and handle it in ways that mimic natural processes and volumes.

For cistern design, for example, the total runoff collected depends on the efficiency of the collection system and the cistern size. For bioretention, runoff handling depends on the ratio of impervious to bioretention surface area, the depth and type of soil media, the underlying soil characteristics, and the types and density of vegetation. For porous surfaces that are hard (e.g. porous concrete) the vegetation variable is removed while the rest remains. For tree planter boxes more reliance is placed on the ability of the tree to evapotranspire runoff volume and less on deep percolation.
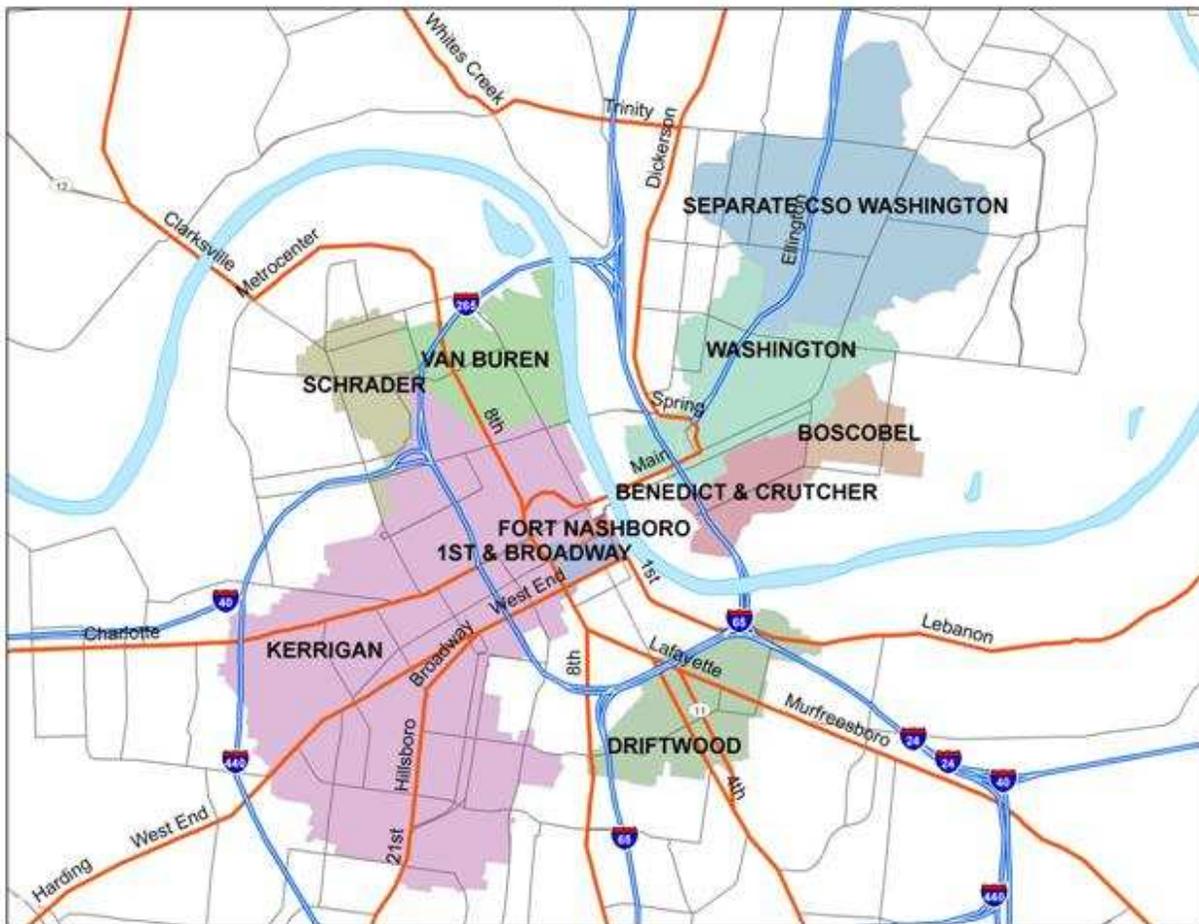
Figure 3.1—Study Area.

Table 3.1—Basin Characteristics.

Basin	Area	Basic Land Use			
	Basin Area (acres)	Total Impervious Area (acres)	% of Basin Area	Total Pervious Area (acres)	% of Basin Area
1st & Broadway	84	70	83.1%	14	16.9%
Benedict Crutcher	277	117	42.2%	160	57.8%
Boscobel	230	81	35.4%	149	64.6%
Driftwood	612	304	49.7%	307	50.3%
Ft Nashboro	22	18	81.6%	4	18.4%
Kerrigan	3388	1797	53.0%	1591	47.0%
Schrader	347	123	35.4%	224	64.6%
Van Buren	534	265	49.6%	269	50.4%
Washington	860	357	41.5%	503	58.5%
Washington Sep.	1524	459	30.1%	1065	69.9%
TOTALS	7878	3592	45.6%	4286	54.4%
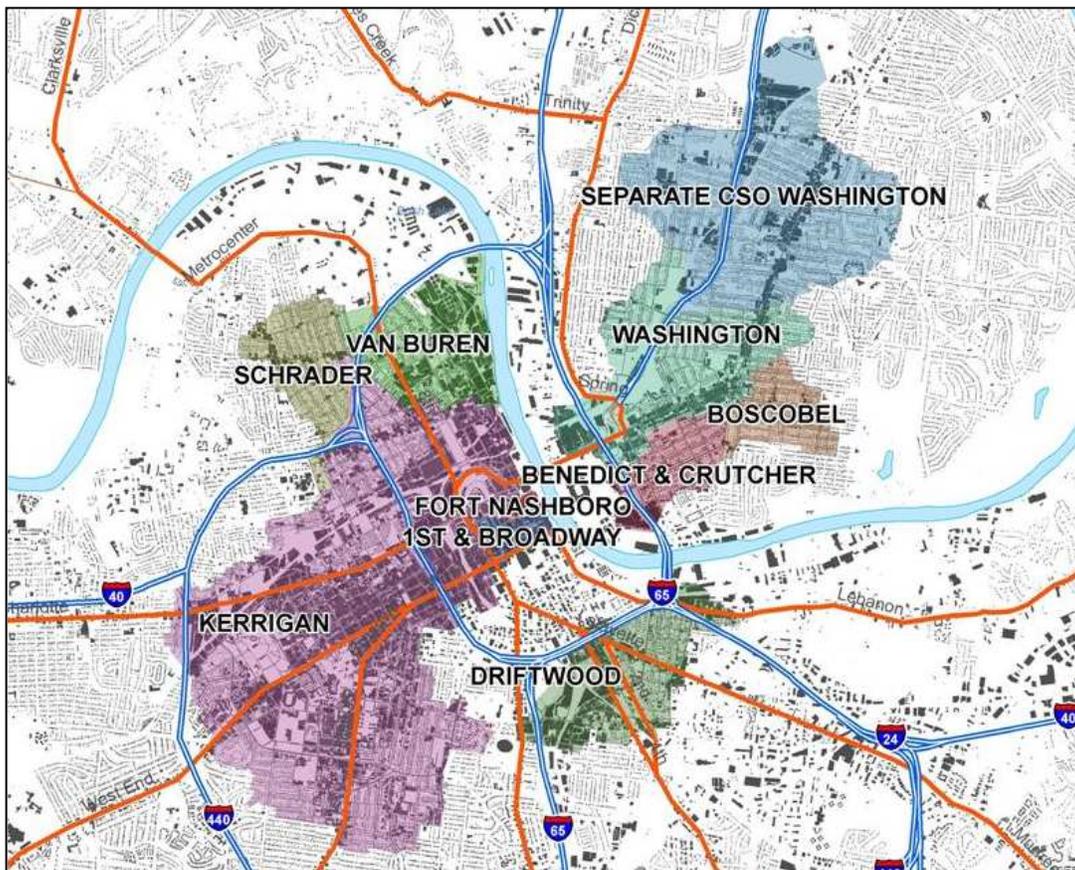
Figure 3.2—Impervious Area Coverage (without roads).

Table 3.2—Distribution of Impervious Area Features.

Basin	Area	Impervious Area Distribution			
	Basin Area (acres)	Building Footprint (acres)	Roads (acres)	Parking (acres)	Other (acres)
1st & Broadway	84	39	17	13.0	0.12
Benedict Crutcher	277	36	44	37.2	0.10
Boscobel	230	40	35	6.3	0.06
Driftwood	612	90	94	119.4	0.26
Ft Nashboro	22	12	5	1.9	0.00
Kerrigan	3388	645	505	640.0	7.34
Schrader	347	48	56	18.5	0.20
Van Buren	534	96	68	100.9	0.21
Washington	860	108	132	114.1	3.56
Washington Sep.	1524	193	141	124.1	0.63
TOTALS	7878	1308	1097	1175	12
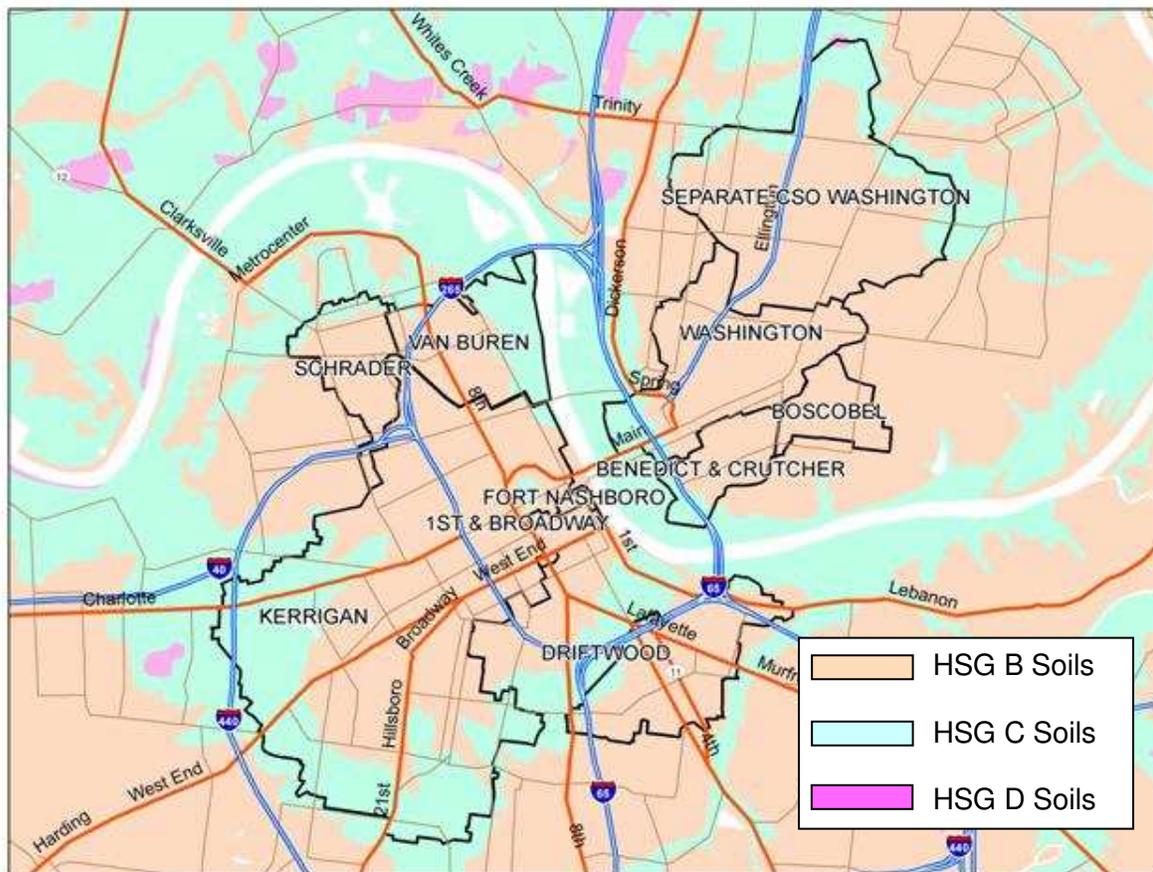
Figure 3.3—Distribution of Hydrologic Soil Groups.

Table 3.3—Distribution of Hydrologic Soil Groups.

Basin	Basin Area (acres)	% B Soils	% C Soils	% D Soils
1st & Broadway	84	100.0%		
Benedict Crutcher	277	78.8%	21.2%	
Boscobel	230	100.0%	0.0%	
Driftwood	612	87.7%	12.3%	
Ft Nashboro	22	100.0%		
Kerrigan	3388	64.9%	34.9%	0.2%
Schrader	347	85.0%	15.0%	
Van Buren	534	58.0%	41.3%	0.7%
Washington	860	88.8%	11.2%	
Washington Sep.	1524	79.9%	19.9%	0.2%
TOTALS	7878	74.6%	25.2%	0.2%

Table 3.4--Parent Soil Hydrologic Characteristics.
(1971-2006 hourly data)

Soil Type	Annual Evapotranspiration (in)	Annual Surface Runoff (in)	Annual Infiltration (in)
Average Annual Precipitation = 48.3 inches			
HSG A CN = 39	21.7	.48	26.2 @ 0.43 in/hr
	45%	1%	54%
HSG B CN = 61	21.8	.97	25.5 @ 0.26 in/hr
	45%	2.0%	53%
HSG C CN = 74	21.6	6.19	20.5 @ 0.06 in/hr
	45%	13%	42%
HSG D CN = 80	23.1	12.78	12.3 @ 0.02 in/hr
	48%	26%	25%
100% Imp. CN = 98	4.4	43.8	0.0 @ 0.0 in/hr
	9.0%	90.8%	0.0%
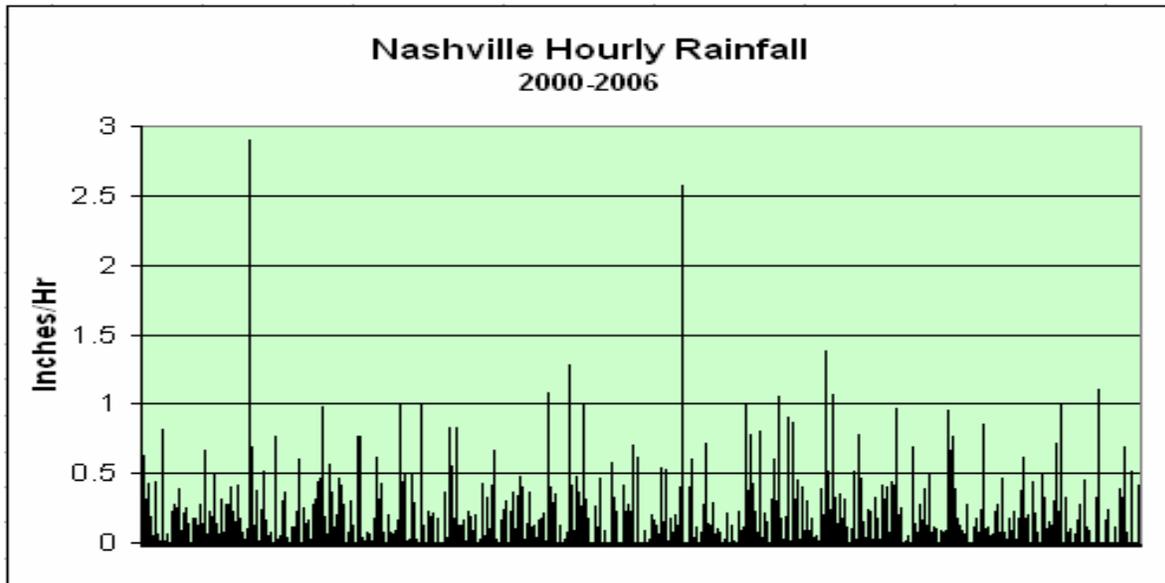
Figure 3.4--Nashville Hourly Rainfall Histogram (2000-2006).
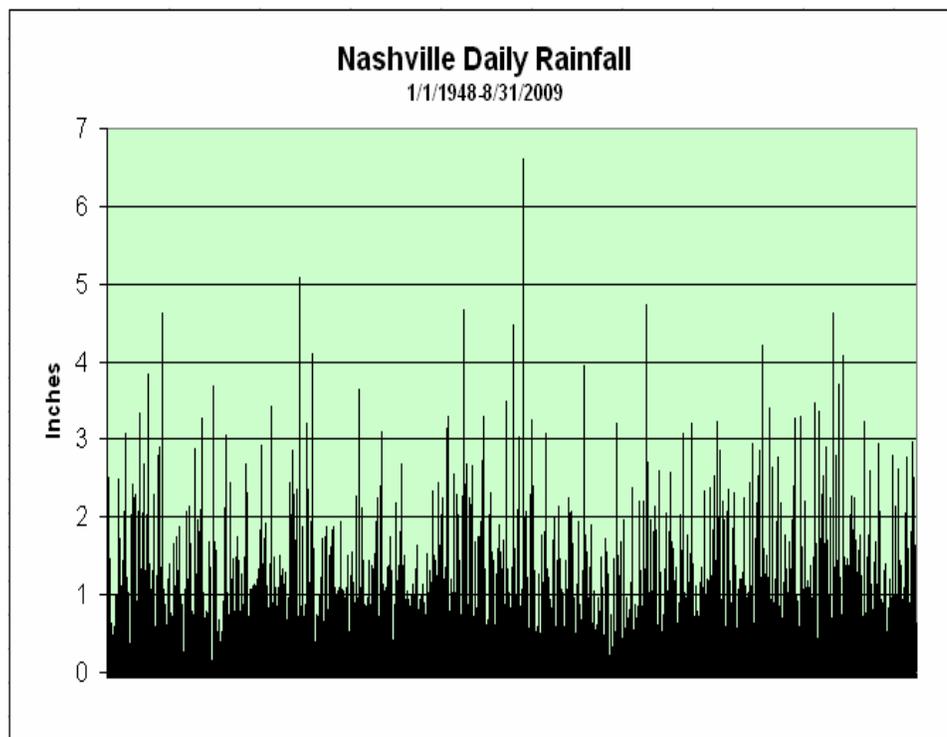
Figure 3.5--Nashville Daily Rainfall Histogram (1948-2009).
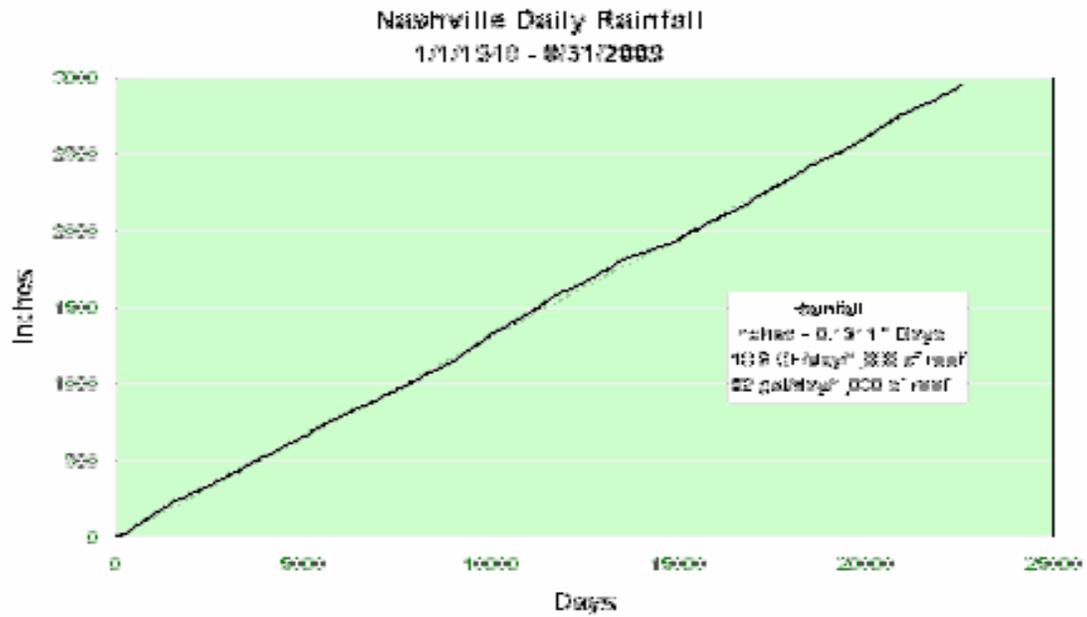
Figure 3.6--Nashville Daily Rainfall Values (1948-2009).
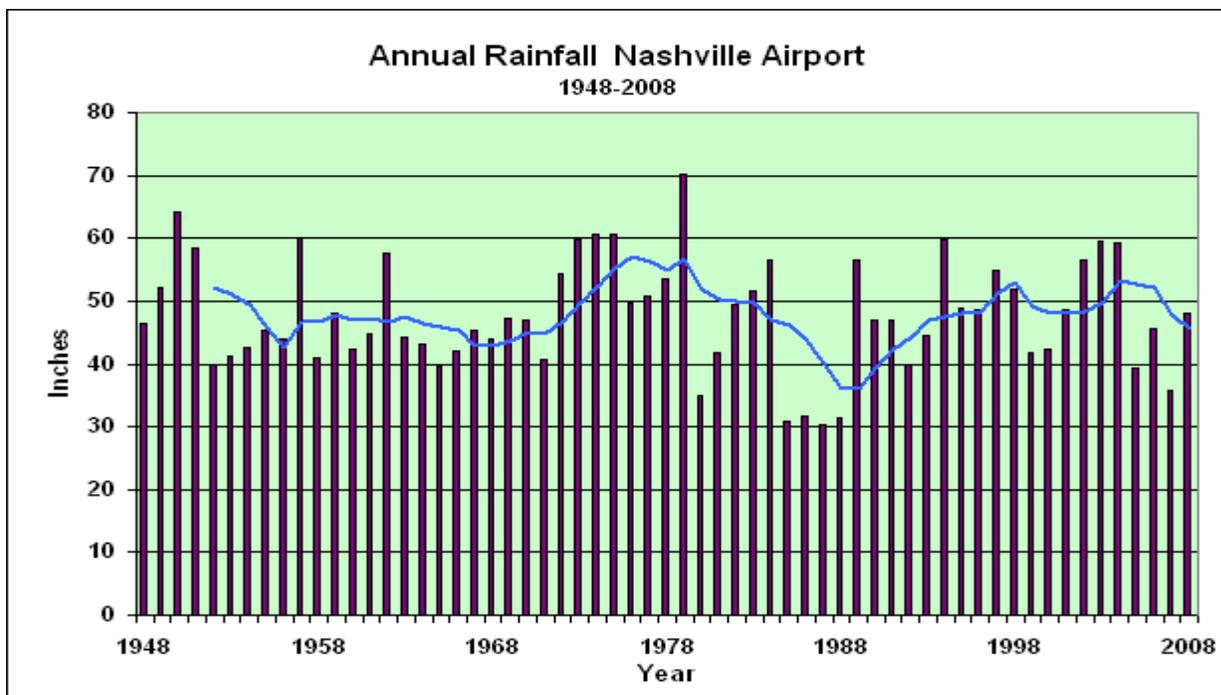
Figure 3.7—Nashville Annual Rainfall Totals (1948-2008).

3.2 Green Infrastructure Implementation Factors

There are a number of related considerations when planning the use of Green Infrastructure. They are grouped here in terms of: objective factors, scale factors, timing factors, effects factors, and uncertainty factors. Each has a place in the design consideration both on a site and within a watershed.

3.2.1 Objective Factors

The purposes for the use of Green Infrastructure vary from community to community and even site to site. Key reasons given to use GI include:

- Replenishment of groundwater
- Enhancement of eco-systems
- Creation of a more natural appearance and aesthetic
- Support for enhanced property value
- Protection of stream stability
- Reduction of volume to a CSS
- Reduction in the need for large drainage infrastructure
- Reduction in local or site maintenance costs
- Reduction in life cycle costs for buildings or outside landscaped areas
- Reduction in heat island effect or improvement in air quality

Depending on the purposes for GI the actual implementation and types of approaches can vary. For example, if a site uses large amounts of irrigation water and has a large roof area, a natural approach would be to consider a cistern to catch the rainfall. But if the demand and rooftop area are not well matched the ability of such an approach may be limited.

Nashville obtains its drinking water from the Cumberland River. Therefore the replenishment of groundwater for drinking water supply is not important. However, the replenishment of groundwater to support the hydrologic character of neighborhood streams is important because streams are significantly impacted by the conversion of inter-flow and slower seepage feeds to direct surface discharge from efficient hard-surface drainage systems. This may mean that infiltration is more important in areas where surface water flow exists (or could be restored) and its protection and enhancement are valued. This might shift focus to neighborhoods with significant stream length that eventually joins the Cumberland River.

As consideration for the use of GI moves from the downtown area to neighborhoods and more remote commercial areas, the types and frequency of application of various practices will naturally change. The suite of practices considered here spans the range of expected application milieus.

3.2.2 Scale Factors

Unlike large CSS construction projects such as tunnels or large holding ponds, GI operates on a distributed and small scale relying on low cost natural techniques and the accumulation of results to be effective. The ability of GI to make a measurable difference will, therefore, vary from basin to basin and site to site. For example, the placement of a 55 gallon rain barrel in the runoff flow path from a rooftop to an existing grassy area for a residential structure that is not directly connected to the CSS system may be small (in terms of volume reduction). But the combined use of both disconnection and a suitably positioned rain barrel (or barrels) may make

a significant difference if the grassy area to which the downspout is now directed is small and easily overwhelmed by runoff. Or, the placement of a suitably sized bioretention area can greatly reduce the runoff volume and peak from parking areas or rooftops provided parent material infiltration rates are sufficient and construction practices do not compact the underlying soil.

3.2.3   Timing Factors

Not all gallons captured by GI practices are equally effective in reducing overflows even if they are all equal in reducing total runoff volume. For example, removing runoff from the first inch of rainfall from the system may not reduce a single overflow if that initial runoff could have been easily handled by capacity within the wastewater treatment plant. But there are locations within the CSS area where placement of GI might directly reduce overflows due to the timing of runoff accumulation. No attempt has been made, except generally based on basin characteristics supplied by MWS staff, to quantify the specific ability of GI practices to reduce actual overflows. Models have been constructed of the CSS system into which GI practices can be added and assessed. Such future modeling effort may help direct the placement and prioritization of future GI projects.

3.2.4   Effects Factors

The law of unintended consequences always comes into play when new approaches to old problems are tried. The CSS area subsurface soil, rock and groundwater flow configuration is varied and unpredictable. For example, if more runoff is infiltrated into underlying soils, where will that additional water go, and what will its impact be?

Several foundation excavations in the CSS area have uncovered both perennial and ephemeral springs, creating the need to pass the water safely around or out of the foundation location. Should increased infiltration be encouraged where proximity to building foundations may be an issue?

Infiltrated stormwater is not always pure. While runoff from typical urban and suburban settings is polluted, those pollutants can generally be removed by the soil complex into which it is diverted. This, however, is not the case with specific pollutants which may be found in runoff from polluted industrial sites or in street runoff when salts have been heavily used. While the latter has not been seen to be an issue in southern climates, the former can be an issue and will limit the use of infiltration from such sites.

3.2.5   Uncertainty Factors

Uncertainty exists in both physical unknowns (underlying soils, weather variability, actual quality of runoff, etc.) and in policy and cultural unknowns (future land use and zoning changes, the reliability of private maintenance of GI practices, future budget limitations, etc.). For example, the presence of a water table or impenetrable rock close to the bottom of an infiltration GI structure will render it much less effective than basic calculation would show. Or, if a number of rain gardens were to be constructed in residential areas what kind of policy changes might be necessary to insure their long term effectiveness, not to mention existence?

Consideration of the use of GI practices attempts to take into account these factors, even implicitly, and to seek to accommodate them in the designs and policies related to GI use. For example, in design, there will be a limitation on the kinds of land use that can be allowed to run into the infiltration practices. In policy there will be a need for a maintenance agreement to be signed if GI practices are allowed.

The following sections discuss a selection of Green Infrastructure practices:

- ◆ Rainwater Harvesting
- ◆ Green Roofs
- ◆ Urban Trees
- ◆ Structural Control Measures
  - • Bioinfiltration
  - • Permeable Pavement
  - • Tree Planter Boxes

3.3 Rainwater Harvesting

Typical domestic indoor per capita water use is 70 gallons per day (gpd); however consumptive use data has shown that outdoor water use can constitute 25% to 60% of overall domestic demand, increasing the per capita domestic use to 165 gpd. Rainwater harvesting is becoming a popular alternative to using potable water for outdoor use – and may have application in runoff volume reduction.

As explained in Section 2, rain barrels, cisterns, and tanks are structures designed to intercept and store runoff from rooftops for alternate uses compatible with local codes and site needs. Rain barrels are often used on a small residential scale while cisterns and tanks are used for general applications. These systems may be above or below ground, and they may drain by gravity or be pumped. Stored water may be slowly released to a pervious area, used for irrigation, or plumbed into buildings per code for use inside, typically in toilet flushing. Figure 3.8 shows underground cisterns at the HG Hill Center in Green Hills used for irrigation.

Facts About Stormwater Reuse:

✓ The CSS area rooftops generate 1.36 billion gallons of runoff annually.
✓ On average, a 55-gallon rain barrel can capture 19% of the runoff from a one thousand square foot roof or 55% of a 250 sq.ft. roof, if it is drained within 48 hours of each filling.
✓ A rain barrel on a one thousand square foot roof drained in 48 hours removes 4,500 gal/yr.
✓ If 10% of all single family homes were outfitted with two barrels each over 9 million gal/yr could be diverted.
✓ It would take a 1,100 gallon cistern to remove 80% of the runoff from a one thousand square foot roof.
✓ On average, runoff from a one thousand square foot roof can handle the grey water needs of 10 people.

3.3.1 Key Considerations

There are many reasons someone may employ a rainwater capturing device, and those reasons will drive both the physics and economics of sizing and placement:

💧 Reduction of domestic water consumption
💧 Reduction of wastewater
💧 Reduced volumes into combined sewer systems
💧 Replenishment of groundwater through slow release

There is normally a balancing of the ultimate demand and supply of rainwater. Because rainfall is not predictable, there must be a backup system where irrigation or grey water use is envisioned and lack of rainwater supply would cause problems. Current Nashville code requirements may prohibit or put certain restrictions on the use of grey water systems. There is a concern that the systems may become interconnected with the domestic

Figure 3.8—Example of Underground Cistern.

water supply system.

Systems must provide for safe storage, overflow or bypass of large storm events. Placement of storage elements higher than areas where water will be reused may reduce or eliminate pumping needs.

For cistern design the total runoff collected depends on the efficiency of the collection system and the speed of use. These techniques only serve as an effective stormwater volume reduction function if the stored water is emptied between storms, freeing up storage volume for the next storm.

Metal roofs designed for collection purpose can attain better then 90% annual capture. Uneven flat roofs can be below 70% average annual capture. A standard coefficient of 0.8 (80%) is often assumed for most purposes. Referring to the rule of thumb established in Section 3.1.4 and Figure 3.6, for a normal rooftop in Nashville the runoff is about 65.5 gallons per day per thousand square feet.

82 gallons of rainfall/day * 0.80 = 65.5 gallons of runoff/day

Of course there may be many days without rainfall leading to the cistern becoming dry, or there may be a deluge leading to overflow and lost water. The design balance is to determine what is more important – a dry cistern or less volume captured.

3.3.2   CSS Area Analysis

The total area of rooftops in the CSS area is 1,300± acres generating 1.36 billion gallons of runoff per year. Note that average annual rainfall, based on daily readings at the airport, is 48.3 inches, and with an efficiency factor of 0.8 runoff would be about 38.6 inches.

38.6 inches of runoff/year * (1 ft/12 in) * 1,300 acres * (43560 sq.ft./acre) =
182 million cu.ft. of runoff/year = 1.36 billion gallons of runoff/year

Simulations were run for three conditions to see what cistern size, per one thousand square foot rooftop, would be required to capture various percentages of annual runoff (RO): demand equals half runoff, demand equals runoff, and demand is twice runoff – all on a constant daily demand basis. Demand at twice the runoff means that demand per one thousand square foot rooftop is twice the expected runoff of 65.5 gallons per day, and so on. Figure 3.9 shows the result.

As can be seen from the Figure the "knee in the curve" is between 200 and 1000 gallons storage per one thousand square feet of roof area (for the given demand conditions). When the demand is low it is easily satisfied with a lot of lost runoff (pink curve). As the demand reaches the average daily runoff the curve moves slowly upward.

On a CSS area wide basis, to capture 80% of the rooftop runoff (1.09 billion gallons), matching demand to rainfall, would require 62.3 million gallons of storage or a ratio of 17.45 runoff gallons for every storage gallon.
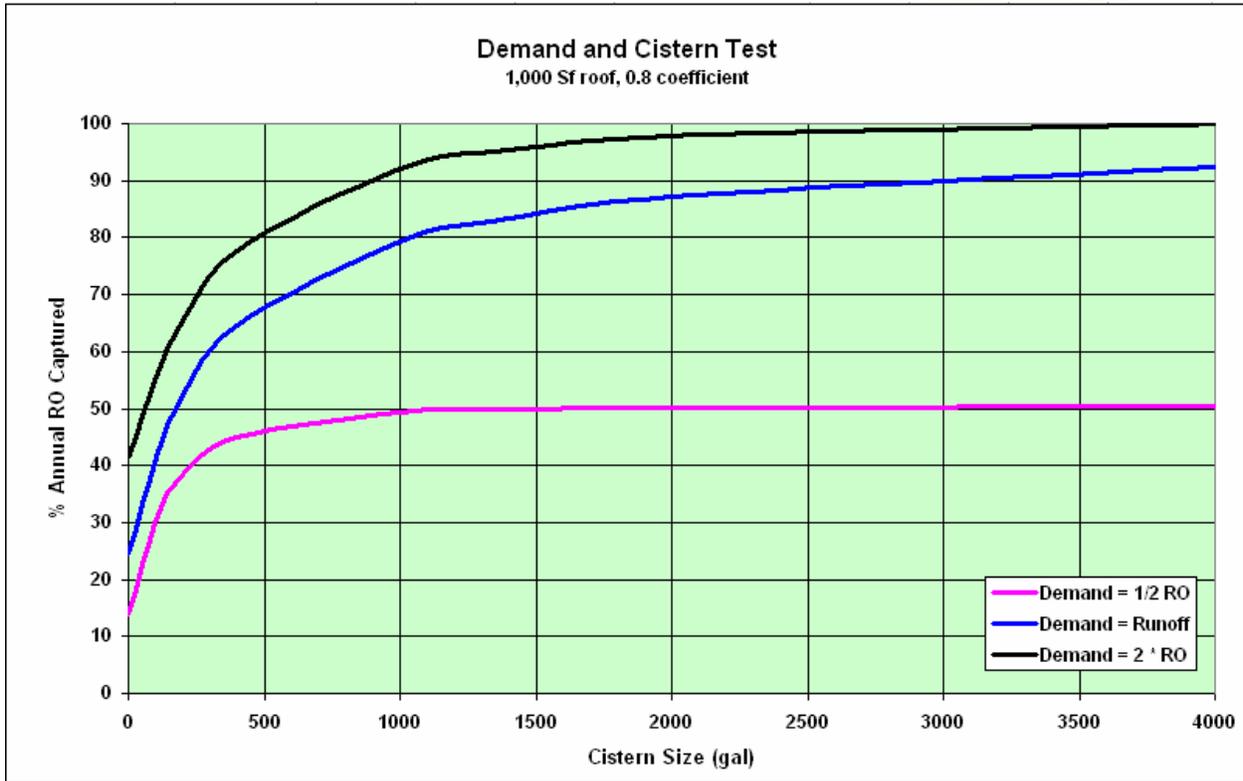
Figure 3.9—Cistern Test for Three Demand Conditions.

Rain Barrels

Nashville Metro Water Services (MWS) promotes the use of rain barrels for the conservation of water for single family residential homes. The current model available for purchase (shown in Figures below) has a capacity of 55 gallons and an adjustable spigot at the bottom. The concern about rain barrel use is that homeowners will forget to empty them between storms rendering them ineffective, as shown in Figure 3.11.

Figure 3.10--Nashville Standard Rain Barrel.

Figure 3.11--Full Rain Barrel.

A continuous simulation of hourly rainfall data from 2000 to 2006 was applied to a one thousand square foot roof with one, two and four 55-gallon rain barrel systems to ascertain the ability of rain barrels to remove volume from the CSS. Drain times ranged from one hour to one week. It is assumed that the drainage of the barrel is to a grassy or garden area that can absorb the barrel discharge.

Figure 3.12 shows the results of this analysis. A 55-gallon rain barrel can capture only 0.09 inches of runoff from a one thousand square foot rooftop. Thus, there is a rapid decline in ability to capture volume as the rain barrel drain time increases.

Figure 3.13 shows the result for a single barrel with a 48 hour (2 day) trickle drain time with varying rooftop sizes draining to it. Thus, for example, if a rain barrel that drains within two days is placed for every one thousand square feet of rooftop the barrels will reduce runoff by about 19%. This assumes that the current configuration is that the roof leaders connect directly into the CSS. Recall that the average runoff from a one thousand square foot rooftop is 65.5 gallons per day. If a rain barrel can capture 19% of that amount on an average annual basis then it captures an average of 12.4 gallons per day or 4,500 gallons per year for that size of roof.
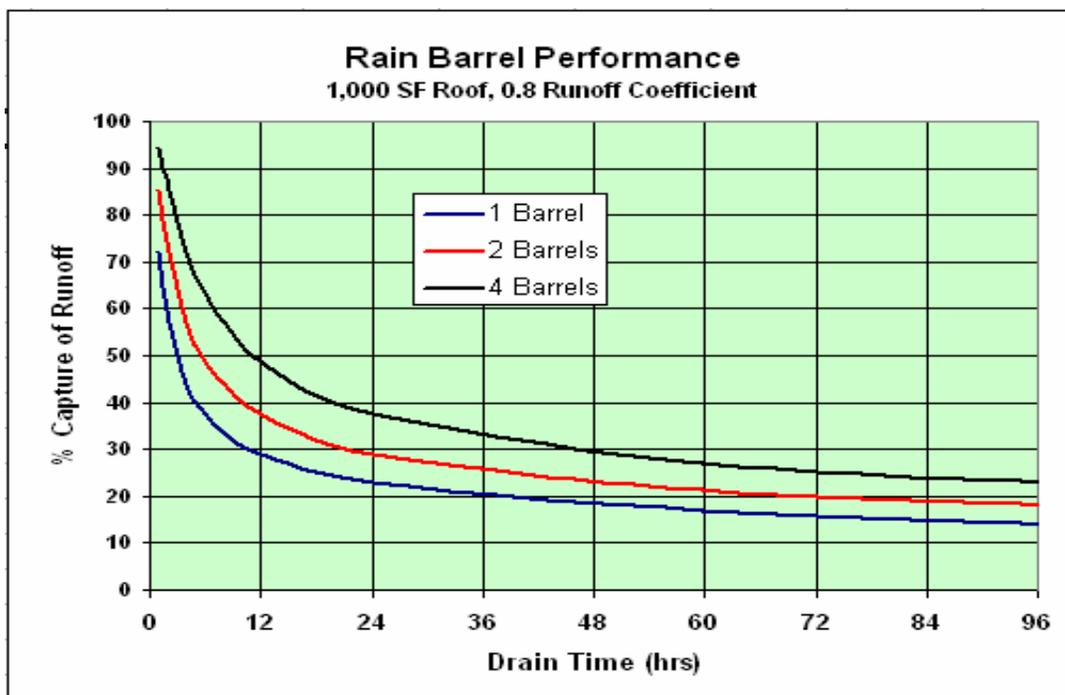
Figure 3.12—Runoff Capture of Various Rain Barrel Configurations.
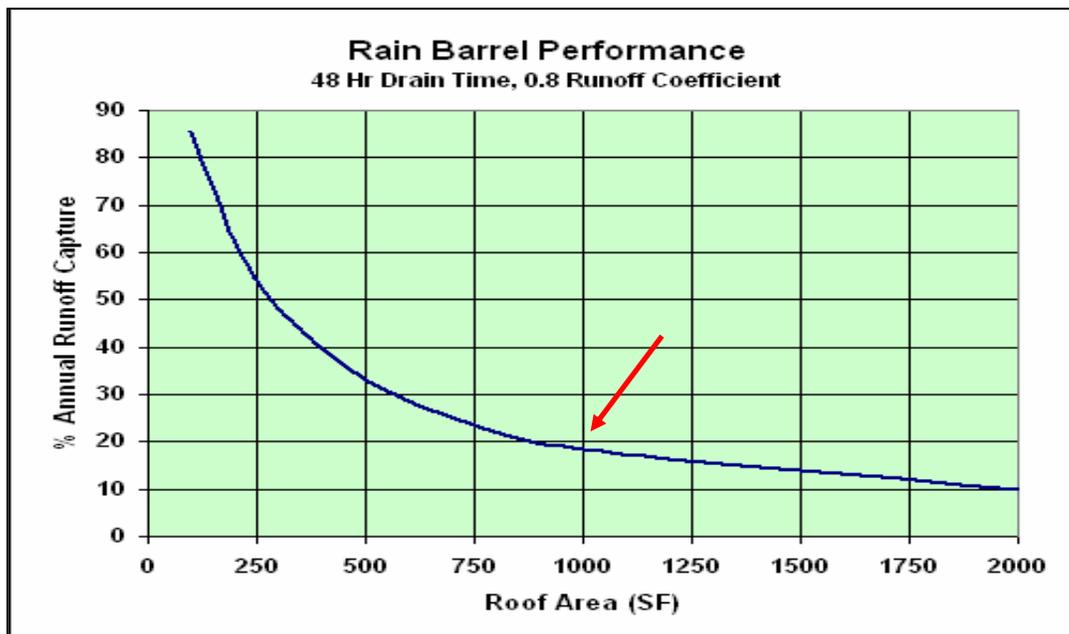
Figure 3.13--Rain Barrel Capture Efficiency Based on Roof Area.

Looking at the CSS area as a whole, an estimate can be made of the ability of rain barrels on directly connected residential structures to reduce the volume of runoff. Table 3.5 below gives a summary for the standard 55 gallon MWS rain barrel applied at a rate of two barrels per house. The barrels are set to fully drain in 48 hours from full to empty.

Table 3.5—Ability of Rain Barrels to Remove Runoff Volume.

Basin	Area				Residential Structures - 55 gal rain barrel, 48 hr drain time							
	Basin Area	Residential Rooftop	Num. of Res. Structures	#Barrels @ 2 per house	Roof Area Per Barrel	10% Coverage		50% Coverage		100% Coverage	
	acres	sq ft			sq ft	gal/yr	% RO	gal/yr	% RO	gal/yr	% RO
1st & Broadway	84	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benedict Crutcher	277	575,253	388	776	741	333,214	2.2%	1,666,000	11.0%	3,332,000	22.0%
Boscobel	230	1,371,401	1,041	2,082	659	877,000	2.5%	4,387,000	12.5%	8,774,000	25.1%
Driftwood	612	543,939	436	872	624	364,000	2.7%	1,820,000	13.3%	3,640,000	26.6%
Ft Nashboro	22	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kerrigan	3388	2,845,647	2,013	4,026	707	1,716,000	2.3%	8,582,000	11.6%	17,164,000	23.2%
Schrader	347	1,287,641	1,074	2,148	599	890,000	2.8%	4,451,000	13.9%	8,901,000	27.7%
Van Buren	534	565,003	458	916	617	382,000	2.7%	1,908,000	13.5%	3,816,000	26.9%
Washington	860	1,833,238	1,399	2,798	655	1,178,000	2.5%	5,890,000	12.6%	11,779,000	25.3%
Washington Sep.	1524	4,286,756	4,071	8,142	526	3,293,000	3.1%	16,467,000	15.7%	32,935,000	31.3%
TOTALS	7878	13,308,878	10,880	21,760		9,033,214		45,171,000		74,595,000	

For example, there is a current effort in planning to place rain barrels within the Boscobel basin. This Table shows that, at two barrels per house, 877,000 gallons can be removed from the CSS with 10% of the homes being so fitted. These numbers assume that the rainfall intercepted would have gone into the CSS and that it does not find a way into the system otherwise.

Two examples will be given to further illustrate these concepts.

3.3.3 Illustrative Examples

Illustration #1 – Medical Clinic

A 33,000 sq.ft. office building rooftop is going to be used to provide for a grey water demand of about 1,200 gpd maximum including weekends. Given the rule of thumb in Section 3.1.4 and Figure 3.6, this is well within a feasible range as a rooftop that size can generate (0.8 efficiency coefficient) over 2,100 gpd.

Table 3.6 shows the results of several trial cistern sizes. A number of approximate assumptions have been made concerning cost, so actual values are merely reflective of the cost changes as sizes change.

- Columns 1-3 list cistern size alternatives, first cost, and amortized cost plus 5% for maintenance and operations.
- Columns 4-7 show information about capture rates and volumes, as well as cost savings at current combination of water and sewer rates.
- Columns 8 and 9 show cistern overflow information – that is, water that is not captured. This includes both the percent of runoff that overflows, and the percent of days overflows occurred.
- Columns 10-12 show the unmet demand which must be handled through domestic supply.

Table 3.6 Cistern Sizing Trials.

Cistern			Captured Volume				Overflow		Unmet Demand		
1	2	3	4	5	6	7	8	9	10	11	12
Cistern Size (gal)	Initial Cost	Cost/Yr (20-yr life)	Gal/Yr Captured	% RO Captured	% of Demand Met	Water Savings Per Yr	% RO O'flow	% O'flow Days	% Dmd Unmet	% Dmd Unmet Days	Gal/Yr Potable Water
1000	$ 4,094	$ 294	169,700	22%	39%	$ 149	78%	21%	61%	75%	268000
5000	$ 9,615	$ 690	292,000	37%	67%	$ 257	63%	16%	33%	38%	145700
10000	$ 13,889	$ 997	356,800	45%	82%	$ 314	55%	13%	19%	21%	80900
20000	$ 20,062	$ 1,440	406,000	52%	93%	$ 357	48%	12%	7%	8%	31800
40000	$ 28,977	$ 2,080	430,000	55%	98%	$ 378	45%	11%	2%	2%	8100

As can be seen from the Table in column 6, there is decreasing incremental percent of demand met as the cistern gets bigger – indicating that there is a "knee in the curve" where an "optimal" cistern size is attainable. Figure 3.14 shows this curve.

Also, in columns 3 and 7 simple cost saving from not using potable water is insufficient to fully justify the cistern cost.
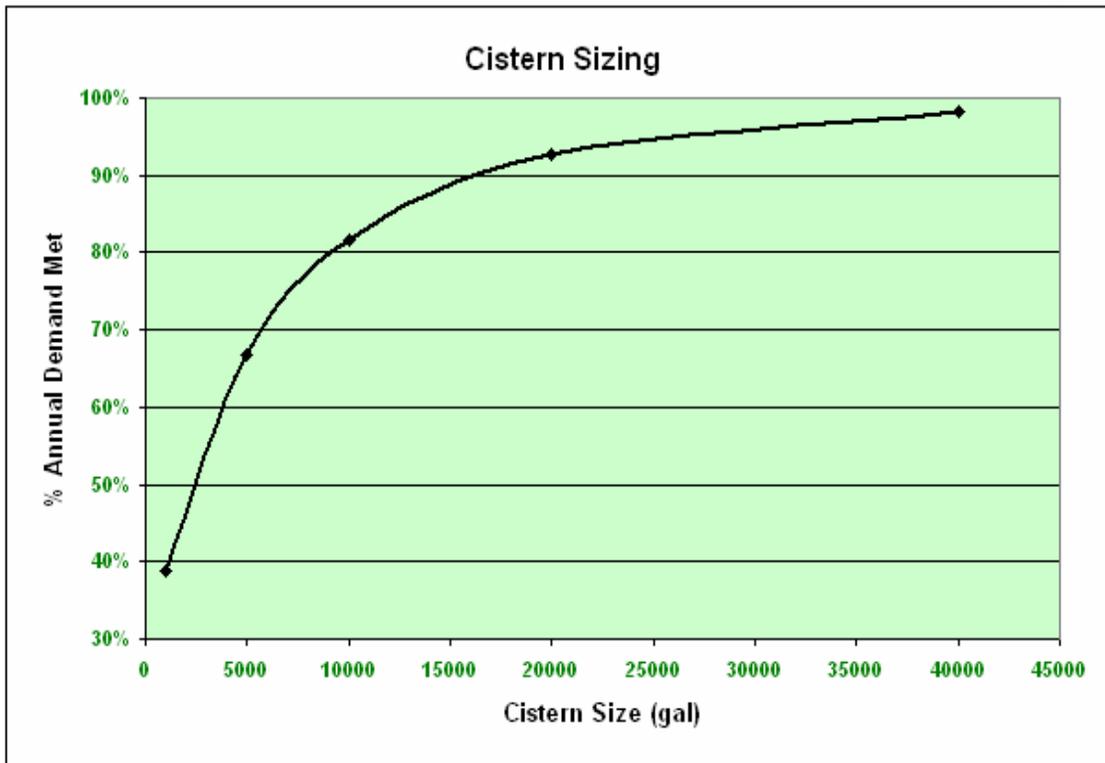
Figure 3.14--Cistern Sizing Example.

Illustration #2 – Farmers Market

The Farmers Market in downtown Nashville wishes to evaluate the use of cisterns to meet part of its irrigation demand. The total roof area available for rainfall capture is 58,400 sq.ft. for four sheds or 74,674 sq.ft. if the additional middle shed is used too. Based on MWS records, the current irrigation demand ranges from less than 64,000 gal/mo in the winter months to almost 400,000 gal/mo in July. The median demand is 190,000 gal/mo and the average is 175,000 gal/mo.
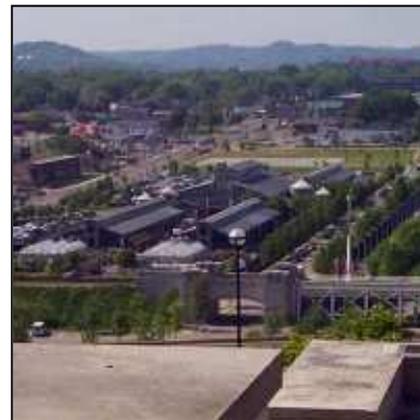
Using an efficiency coefficient of 0.8 and our rule of thumb the total roof can deliver an average of about 145,000 gal/mo – well short of requirements. Trials of different cistern size were run using the monthly irrigation demand from MWS data in the summer only when it is high and distributed on a daily basis.

Figure 3.15 illustrates the outcome of the trials. In this case the demand cannot be met by catching rainfall and supplemental potable water will still be needed.

Depending on the design parameters considered important for the Market, various sizes of cistern could be chosen. If the goal were to find the knee in the curve where a larger cistern

would not provide significant benefit then a cistern in the range of 30,000 to 70,000 gallons would suffice. If, on the other hand, there was a desire to capture as much rainfall as reasonably possible then a much larger cistern would be chosen. For example, a 30,000 gallon cistern total would result in an average of nine days of summer cistern overflow (i.e. lost irrigation water) while a 100,000 gallon cistern would result in only three overflow days on average.
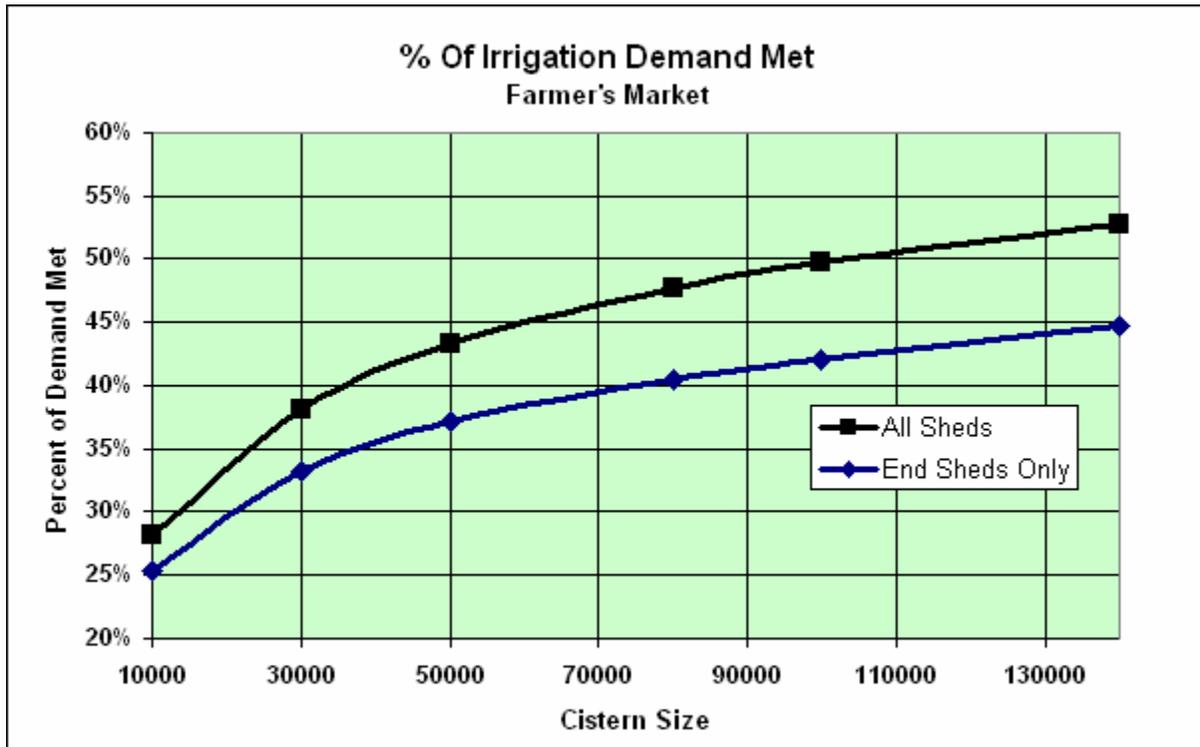
Figure 3.15—Cistern sizing for Farmer's Market.

3.4 Green Roofs

As previously described, green roofs (vegetated roof/eco roof/roof garden) are a system consisting of waterproofing material, growing medium and vegetation. A green roof can be used in place of a traditional roof as a way to limit impervious site area, reduce runoff volume and manage stormwater runoff. And they can provide a garden-like atmosphere for use of the roof. For example, Figure 3.16 shows a green roof on the Pinnacle Building which had been recently completed and in early growth.

3.4.1 Key Considerations

Green roofs are gaining in popularity for a number of reasons including:

- Reduced runoff volumes into combined sewer systems
- Reduction of heat island effect
- Building roof preservation and life-cycle and energy cost reduction
- Reductions in stormwater fees
- Ability to meet regulatory requirements
- LEED™ rating points
- Aesthetics and quality of life values

Although most green roofs consist of lightweight growing medium and low growing succulent vegetation, other more heavily planted systems are possible; in either case the design should be self-sustaining but should also have an alternate form of irrigation. The structural support must be sufficient to hold the additional weight of the green roof. Generally, the building structure must be adequate to hold an additional seven to eight pounds per square foot per inch of media depth saturated weight, depending on the vegetation and growth medium that will be used. Greater flexibility and options are available for new buildings than for reroofing existing buildings, however retrofits are possible. For retrofit projects, an architect, structural engineer, or roof consultant can determine the condition of the existing building structure and what might be needed to support a green roof. Alterations might include additional decking, roof trusses, joists, columns, and/or foundations.

Based on local modeling and other data, green roofs often remove more than 55-60% of average annual rainfall through evapotranspiration and delays water release to the system. Green roofs reduce stormwater volume through evapotranspiration alone. There is no infiltration. Thus it is important to design the plantings and media to maximize this affect.

Facts about Green Roofs:

- ✓ Green roofs have multiple benefits besides runoff volume reduction.
- ✓ There are a total of 2,132 buildings with flat roofs in the CSS area that could provide 20.6 million square feet of green roof area.
- ✓ Based on modeling a typical 4" thick green roof can remove at least 55% of all rainfall from running off, or 26.3 inches of rainfall annually.
- ✓ If all these buildings were used for green roofs they would remove a total of 343 million gallons from the CSS system on an average annual basis.
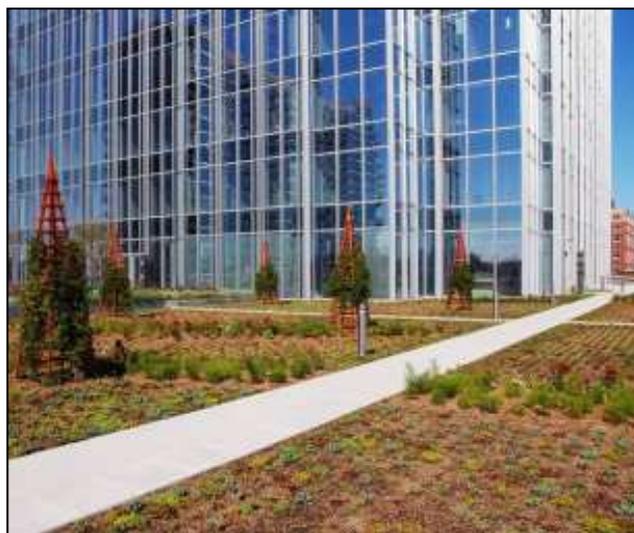
Figure 3.16--Pinnacle Building Green Roof.

3.4.2 CSS Area Analysis

Although green roofs can be used on roofs with pitches up to 25%, this study looked at flat roof areas only. An analysis of both the number of green roof possibilities and the ability of green roofs to remove rainfall volume was performed.

To obtain locations, Geographical Information System (GIS) and Light Detection and Ranging (LiDAR) mapping data was used to develop coverage of flat roofs greater than 100 square feet within the CSS area. First the building polygons were spatially joined with the parcel polygons to produce buildings with land use from the parcel data. This information was used for refinement of the analysis. A terrain dataset was created using the Davidson County raw LiDAR points, county wide break lines, county wide building polygons and the CSS boundary. Next, a TIN dataset was created to get the percent slope. The results were extracted using modified building polygons to get a raster dataset for only the rooftop areas. A statistical analysis for each building was done using the majority slope for data inside each building polygon. The end result data was a point dataset with the slope factor attribute and was joined back to the original building polygons for the final dataset. The analysis did not catch all potential flat roofs in a watershed, but estimates are anticipated to be within 5% on the low side.

Figure 3.17 shows examples of the coverage, and Figure 3.18 shows the coverage for the complete CSS area.

Figure 3.17--Examples of Flat Roof Locations.
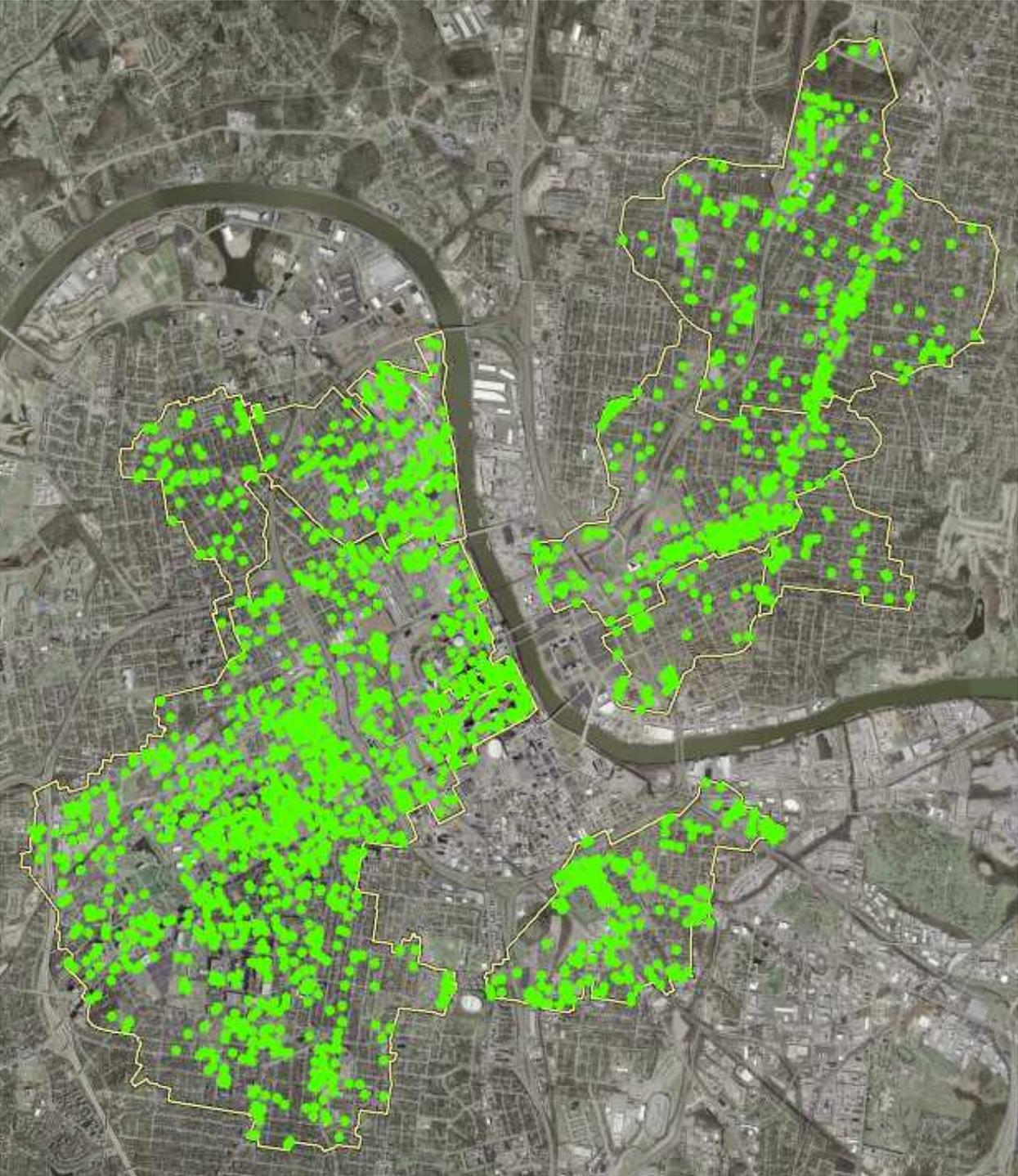
Figure 3.18--Potential Green Roof Sites.

Table 3.7 shows the total flat roof area available in the CSS area. Note that these totals are 25% less than the total flat roof areas allowing for the fact that, on average, 25% of the roof area is taken up with roof stairway access, HVAC equipment, and safety or other access needs.

There are a total of 2,132 buildings in the CSS area that theoretically could have a green roof installed, though no attempt has been made to ascertain structural suitability. These buildings provide 21 million square feet of green roof area.

Continuous simulation modeling of a green roof with 4-inch thick media with a porosity of 0.4, a field capacity of 0.35, and a wilting point of 0.05 was performed. Normal sedum type plantings for the Nashville area were specified.

The continuous simulation was performed for 36 years of hourly rainfall data. Modeling showed that 54.5% of all the rainfall was handled by the green roof through evapotranspiration. Other data shows a higher range into the low 60%. For our purposes, until we can obtain monitoring data in Nashville we will use 55-60% removal. On an average annual basis, this amounts to 26.6 inches of rainfall removed from the CSS system of 343 million gallons of potential runoff.

Table 3.7—Distribution of Flat Roofs.

Basin	Area	Flat Roofs			
	Basin Area (acres)	Flat Roof Area (1,000 sq ft)	Flat Roof Area (acres)	Number of Buildings	Million Gal/Year Removed
1st & Broadway	84	918,000	21.1	67	15.2
Benedict Crutcher	277	210,000	4.82	40	3.48
Boscobel	230	67,000	1.54	22	1.11
Driftwood	612	1,879,000	43.1	185	31.2
Ft Nashboro	22	196,000	4.50	29	3.25
Kerrigan	3388	11,637,000	267	1,129	193
Schrader	347	157,000	3.60	54	2.60
Van Buren	534	1,854,000	42.6	173	30.7
Washington	860	1,515,000	34.8	220	25.1
Washington Sep.	1524	2,266,000	52.0	213	37.6
TOTALS	7878	20,699,000	475	2,132	343

Figure 3.19 depicts percentage of potential flat roofs converted to green roofs versus millions of gallons of runoff removed for a range of annual percent removal from 55-60%.
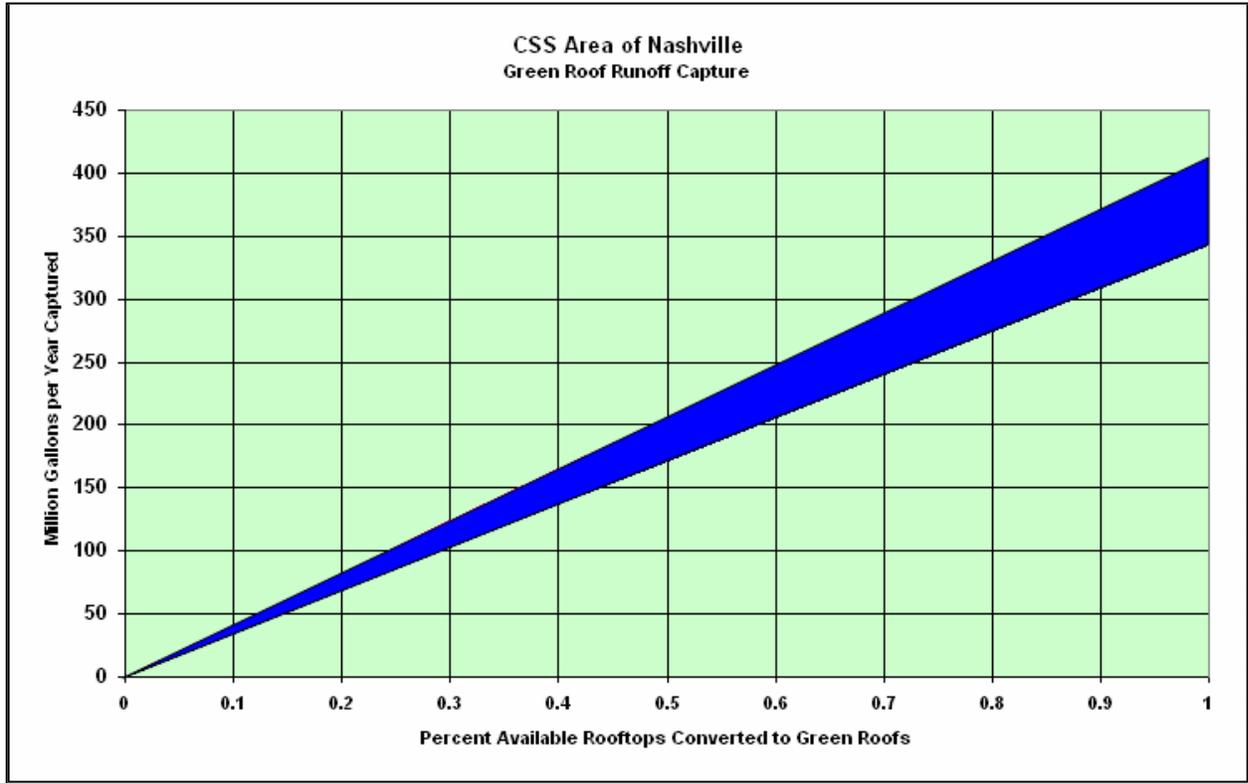
**Figure 3.19—Potential Runoff Capture by Flat Roof
Conversion to Green Roofs.**

3.5 Urban Trees

As Nashville transitions into a more "green" and sustainable community, healthy community forests become ever more important to the quality of life residents experience. The role of urban trees in enhancing the environment, increasing community attractiveness and livability, and fostering civic pride takes on greater significance as communities strive to balance economic growth with environmental quality and social well-being.

Urban trees can also play an integral role in removing stormwater volume from urban areas.

3.5.1 Key Considerations

Trees, and particularly trees in an urban setting, provide a multitude of benefits including: saving energy, reducing atmospheric carbon dioxide, improving air quality, reducing stormwater runoff habitat improvement, noise reduction, increased property tax revenue, reduced street maintenance due to shading, and aesthetics.

Some studies have even claimed crime rate reduction, higher job satisfaction and improved school test scores. A study in the Piedmont area of North Carolina found an average <u>net</u> benefit from tree planting ranging from $12 for smaller trees to about $85 per tree for large trees.[1] Costs were found to range from $21 for small trees to $22 per year for large trees.

Figure 3.20 shows the complex set of relationships that exist with respect to trees and hydrology. The two relationships of interest to us in this study are evapotranspiration (evaporation and transpiration) and interception.

In addition to these relationships there are other complications in consideration of the increased use of urban trees as a stormwater removal device including: utility and other urban infrastructure conflicts, ongoing maintenance, identification of planting locations, local program funding, etc.

> **Facts About Urban Trees:**
>
> ✓ Urban trees have many demonstrable benefits well beyond capture of rainfall.
> ✓ The CSS area has an existing average canopy cover of 19.5% with basins that vary from 0.14% to 33.3%.
> ✓ There are an estimated 51,800 acceptable new tree planting sites adding 811 acres of urban trees and increasing the percent canopy coverage average to 30%.
> ✓ Except for the highly impervious basins the rest of the basins are an average of 10% below their maximum canopy capacity.
> ✓ An additional 167 acres of trees overhanging impervious areas could be planted removing an additional 12 million gallons of rainfall annually.
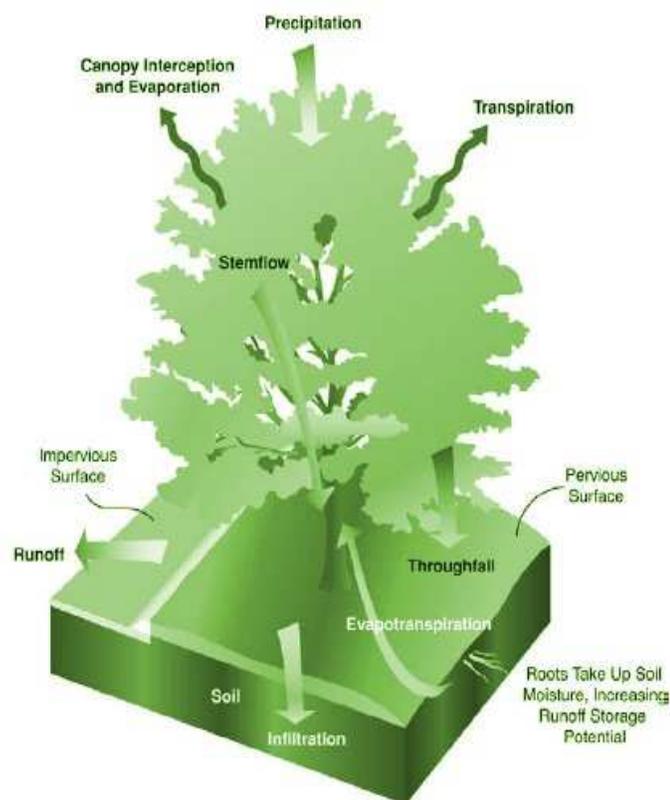
Figure 3.20--Hydrologic Relations and Trees.

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[1] *Piedmont Community Tree Guide*, USDA, Nov. 2006, p.32

3.5.2 CSS Area Analysis

A number of cities have performed an analysis of their urban forests and assessed potential for forest canopy increase. Figure 3.21 shows existing tree canopy for a number of cities.[2] The Nashville CSS area has an existing forest canopy cover of 19.5%. Specific comparisons are difficult to make given the wide ranging character of the entities represented. In all fairness, the areas outside the CSS area have a higher, though unknown, canopy coverage which would raise the average.
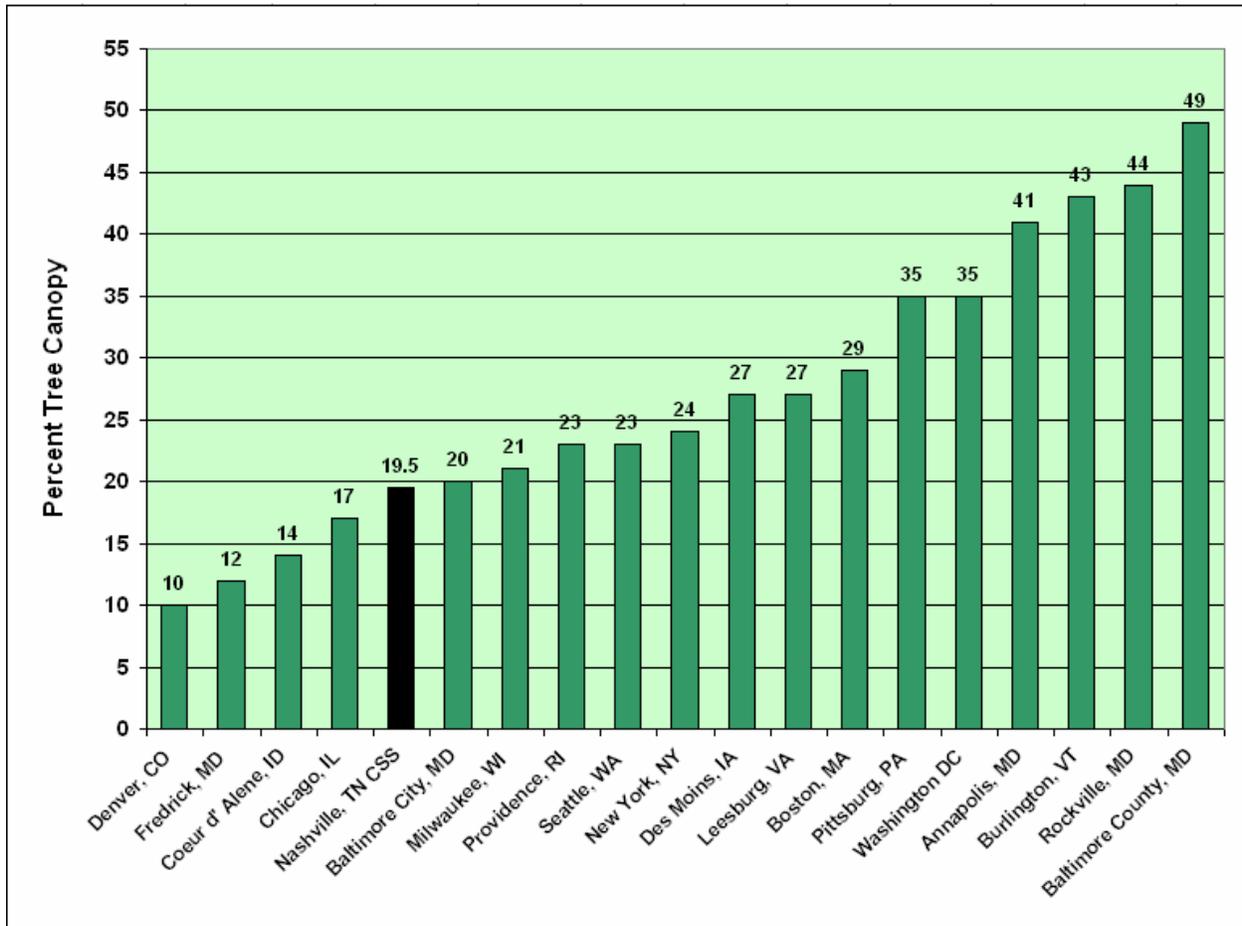
Figure 3.21--Selected City Existing Tree Canopy.

There are two areas of interest to our study which we will estimate using complex tree canopy mapping and continuous simulation modeling: tree canopy interception and evapotranspiration. These are the two factors that most influence rainfall runoff volume reduction.

Existing Tree Canopy
In order to provide a baseline, the existing tree canopy was mapped. Leaf-on color-infrared digital imagery was required to map the existing urban tree canopy (UTC) and other land cover classes. The National Agricultural Imagery Program (NAIP) has 1-meter spatial resolution 4-band multispectral imagery for the entire state of Tennessee. This imagery for Davidson County

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[2] Source: US Forest Service

was obtained and then clipped to the CSS area using ERDAS Imagine image processing software. To extract land cover, a normalized difference vegetation index (NDVI) was first performed, followed by an object-based image analysis approach in Visual Learning System's Feature Analyst, a relatively new remote sensing technology. Existing 6-inch resolution natural color leaf-off imagery was obtained and used to supplement small areas of grass that weren't visible in the NAIP imagery but important for plantable space later in the project.

Tree crowns of varying sizes and spectral characteristics were delineated using automated techniques and select algorithms and then underwent a Quality Assurance / Quality Control (QA/QC) procedure for manual cleanup where algorithms incorrectly identified a tree from another feature. Metro Nashville's existing impervious surface GIS layer was incorporated into the classification workflow, using existing tree canopy and the background vegetation from NDVI as masks. Discrepancies between the 2007 impervious mapping and 2008 NAIP imagery were rectified through an automated process. The remaining land cover classes, water and bare soil, where extracted after masking out the other classes, and all five classes were merged into a single final land cover file. The final 5-class land cover classification included trees/shrub, impervious surface, water, bare soil, and grass/meadow.

Figures 3.22 through 3.24 show examples of the three coverages used in the analysis and the process used to develop existing tree canopy. Figure 3.25 shows the final existing canopy cover percentages by CSS area basin with the NAIP imagery in color-infrared.

Figure 3.22—One Meter Resolution, NAIP Image Viewed In False Color (Color-Infrared).

Figure 3.23—Six Inch Resolution Aerial Photography.

**Figure 3.24--Tree Canopy Cover Polygons
Mapped From 1-Meter NAIP Imagery.**
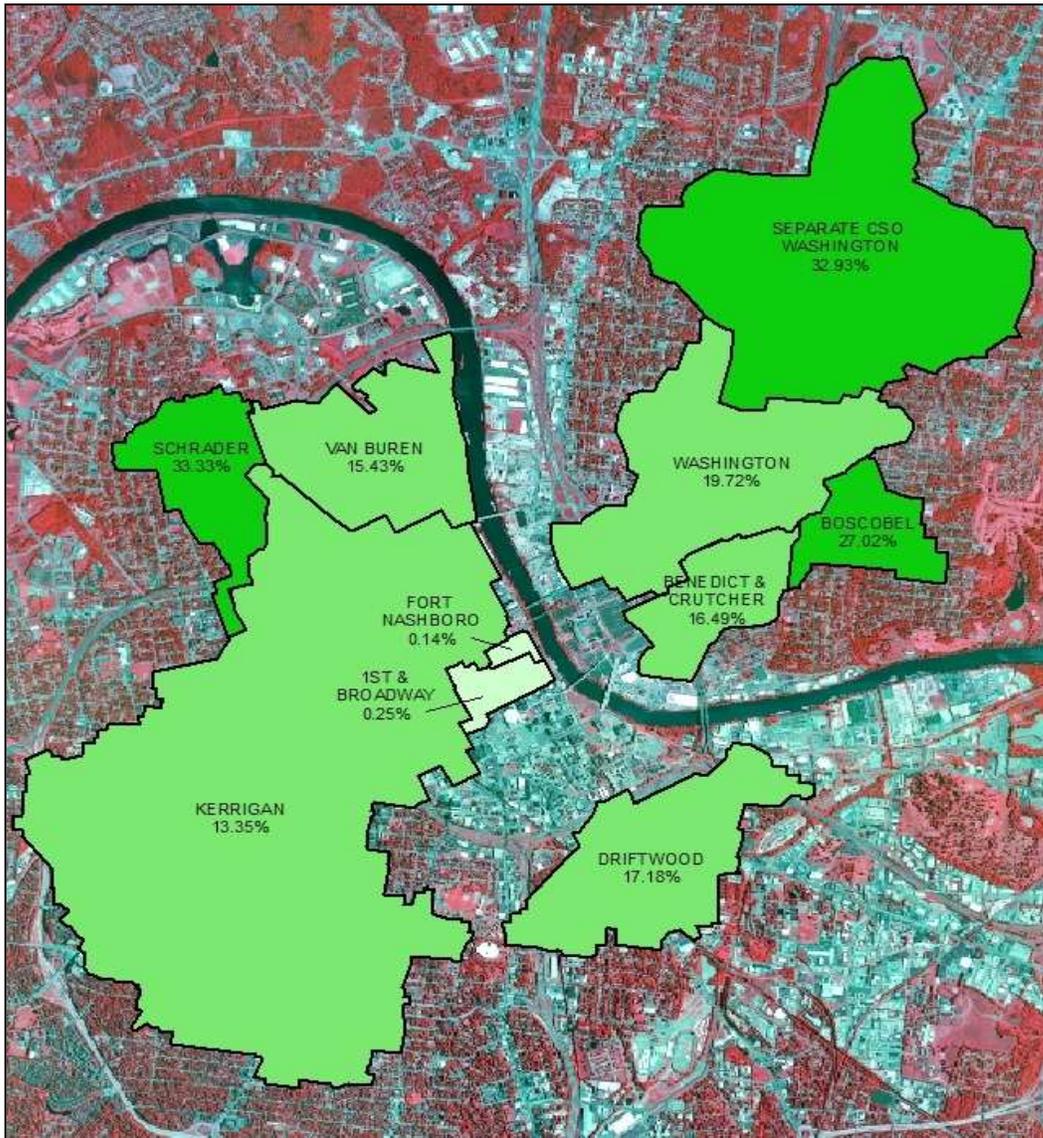
Figure 3.25--Existing Canopy Cover Percentages.

Table 3.8 gives data on the existing tree canopy including trees that overhang impervious versus pervious areas. Notice that 19.5% of the area is covered by canopy though there is wide variation.

Potential Future Tree Canopy
A series of stable and sophisticated geoprocessing models were developed to locate potential tree planting sites based on available grass/meadow land cover. Existing trees were buffered by 10-ft to allow for existing canopy growth and limit future trees from interconnecting. Metro Nashville's planimetric layers were buffered to avoid conflict with paved surfaces and future root growth, specifically buildings by 5-feet and sidewalks by 1-foot. In addition to these exclusion layers, recreation area polygons such as ball fields and road layers were provided by Nashville

Table 3.8--Existing Tree Canopy in Study Area.

Basin	Area	Basic Land Use			Tree Canopy Analysis			
					Existing		Impervious Overhang	
	Basin Area (acres)	Total Impervious Area (acres)	% of Basin Area	Existing Canopy (acres)	% of Basin Area	Existing Imperv. Understry (acres)	% Existing Over Imp. Areas
1st & Broadway	84	70	83.1%	0.21	0.25%	0.13	61.9%
Benedict Crutcher	277	117	42.2%	45.7	16.5%	9.7	21.2%
Boscobel	230	81	35.4%	62.1	27.0%	11.4	18.3%
Driftwood	612	304	49.7%	105.1	17.2%	17.0	16.2%
Ft Nashboro	22	18	81.6%	0.03	0.14%	0.02	66.7%
Kerrigan	3388	1797	53.0%	452.2	13.3%	83.2	18.4%
Schrader	347	123	35.4%	115.7	33.3%	20.8	18.0%
Van Buren	534	265	49.6%	82.4	15.4%	12.8	15.5%
Washington	860	357	41.5%	169.6	19.7%	24.2	14.3%
Washington Sep.	1524	459	30.1%	501.8	32.9%	42.3	8.4%
TOTALS	7878	3592	45.6%	1535	19.5%	222	16.3%

Metro and used to exclude these potential planting site locations. The model did not enable plantings on roofs or in parking lots except where medians existed and could be mapped as plantable area.

Medium sized trees with a 30-foot crown diameter were used in the modeling as an average size at maturity and in most cases, 40-ft spacing was used between planting sites. In some instances, larger spacing and other rules were applied, such as a post-processing model to eliminate planting sites that overlapped after the tree crown buffer was applied, which efficiently cleaned up potential planting sites. Rulesets differed slightly for tree planting locations on private land vs. the public right-of-way, which was created by generating the inverse of the parcel boundaries.

Limitations exist with any model and a few that pertain are provided here. The relatively low resolution of the multispectral NAIP imagery (1-meter) impacted the ability to map small planting sites such as planter boxes, which in a highly urbanized setting such as downtown Nashville can result in identifying less planting sites in critically important areas for mitigating stormwater runoff. Also, there was a lack of on-the-ground data sources such as signage, visibility & safety concerns, overhead & above ground power lines, street lights and other infrastructure that impact the feasibility of tree planting. Without these datasets to guide the model, some planting locations will be invalid when inspected in the field and ultimately the number of planting sites is overestimated.

Figure 3.26 depicts the same portion of the CSS area with the maximum potential of trees applied. Table 3.9 gives statistical information on the maximum number of potential planting sites within each basin, following the set of location rules described above.

Figure 3.26--Maximum Tree Planting Potential.

Table 3.9--Potential Tree Planting Statistics.

Basin	Area	Tree Canopy Analysis				
		Existing	Potential Planting Sites		Potential Final Result	
	Basin Area (acres)	Existing Canopy (acres)	No. Planting Sites	Potential New Tree Canopy (acres)	Total Pot. Tree Canopy (acres)	Maximum Canopy as % of Basin Area
1st & Broadway	84	0.21	42	0.66	0.87	1.0%
Benedict Crutcher	277	45.7	2630	41.1	86.8	31%
Boscobel	230	62.1	1485	23.3	85.5	37%
Driftwood	612	105.1	4269	66.3	171.4	28%
Ft Nashboro	22	0.03	4	0.06	0.09	0.4%
Kerrigan	3388	452.2	19772	310.3	762.5	23%
Schrader	347	115.7	2454	38.4	154.1	44%
Van Buren	534	82.4	3696	57.7	140.1	26%
Washington	860	169.6	6676	105.0	274.6	32%
Washington Sep.	1524	501.8	10745	168.3	670.1	44%
TOTALS	7878	1535	51773	811	2346	30%

Figure 3.27 shows visually the total potential tree canopy as a percent of basin area. Figure 3.28 shows the relationship between basin impervious area and existing and potential tree canopy. There are several key findings from this relationship.
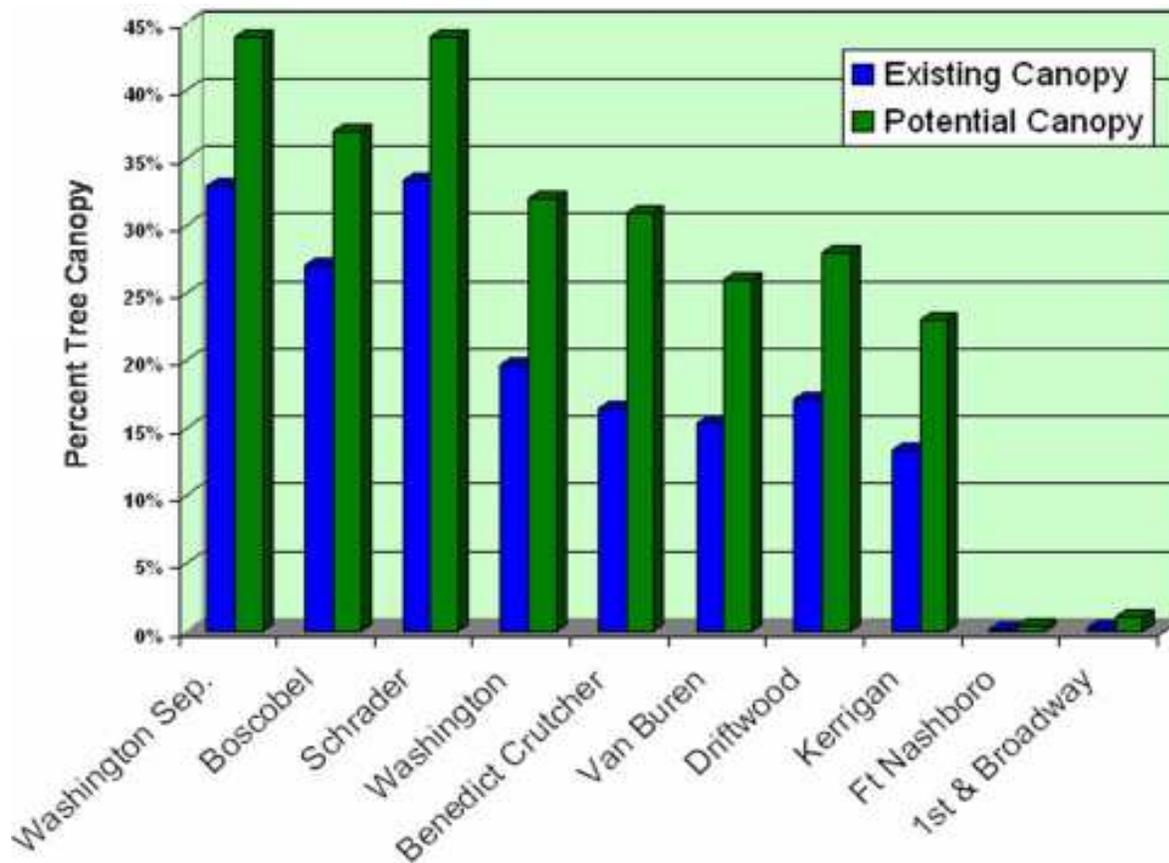
Figure 3.27--Existing and Potential Total Tree Canopy Cover.

The maximum potential tree canopy follows a linear relationship (pink line) which can be expressed as:

$$\textbf{\textit{Max Canopy = 0.68 – 0.82 * \% Impervious}}$$

Except for the two highly impervious basins the current tree canopy in each of the rest of the CSS area basins averages 10% less than its maximum potential.

Tree Planting Prioritization
After buffering tree planting sites by 30-feet, a second set of models was developed to attribute each planting site using GIS overlays. The number of potential sites was too great for even a large-scale tree planting initiative, so it is invaluable to have information on each planting site that enables a user to query the database to determine where & how many sites exist to meet multiple functional objectives, (e.g. stormwater mitigation, energy savings, increased property values, etc). With the final database, each planting site can be queried for:
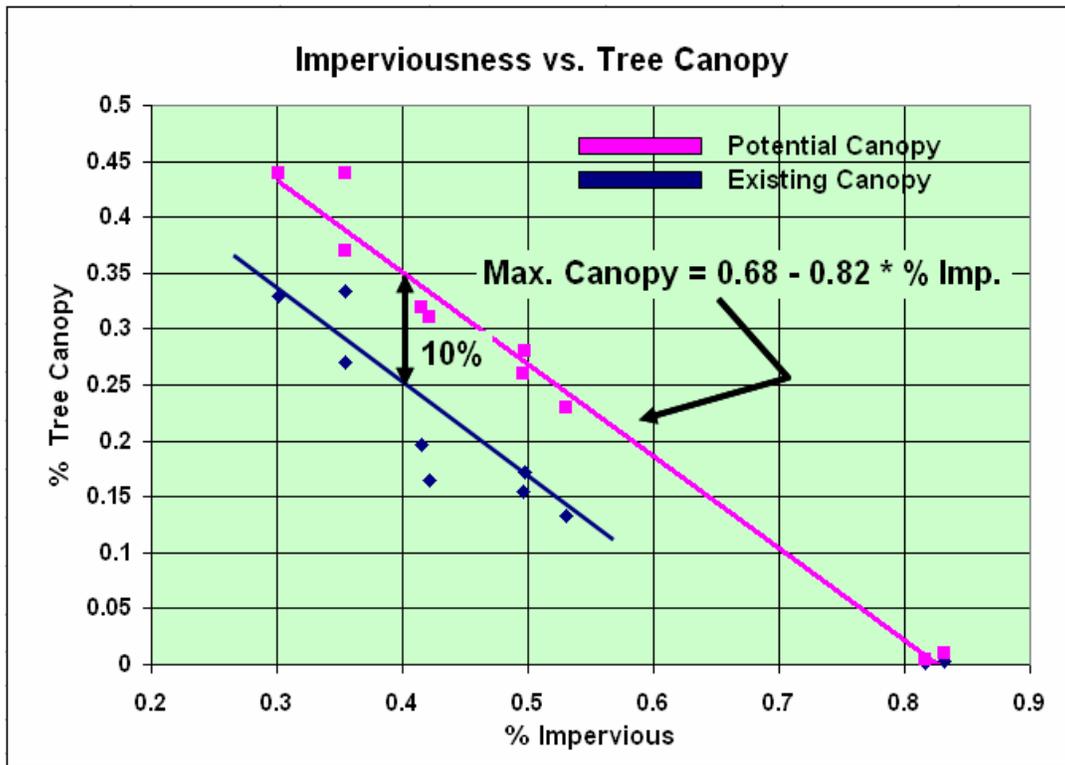
Figure 3.28—Basin Imperviousness vs. Existing & Potential Tree Canopy.

- the land use type it resides on (e.g. public right-of-way, residential, commercial, parks, schools),
- the CSS basin or census block it is in,
- its parcel identification number,
- the number of planting sites in a given parcel,
- the size of that parcel
- parcel street address, and,
- potential "impervious understory area".

For every potential site, this impervious understory area square foot value indicates the potential impervious area in square feet that would be covered one day by the mature tree crown. Using these different attributes, each site can be ranked or queried. For example Figure 3.29 shows a query against the database for trees planted within public rights-of-way. Figure 3.30 shows a query for trees planted near parking lots with at least a 30% overhang of impervious areas.

Trees remove rainfall both by interception and storage in the leaves for later evaporation, and by transpiration through root uptake to the leaves. A rough analysis was performed to estimate the magnitude of both of these factors. Individual site characteristics may greatly change the ability of a tree to remove rainfall volume for that site. Thus these estimates are order of magnitude only, and based on a thirty foot diameter deciduous tree canopy.

Figure 3.29--Trees Planted in Public Right-of-Way.

Figure 3.30--Trees Overhanging Parking Lots 30% or More.

<u>Volume Removal by Trees - Interception</u>
The ability of trees to remove rainfall runoff by interception alone is only incrementally better than the ability of undeveloped shrub and grassy areas from doing so. However, the tree canopy when combined with a grassy or shrub understory provides an additional vertical level of rainfall volume removal. This is particularly pronounced when the tree overhangs impervious areas.

The capability of new downtown tree plantings to remove runoff volume by leaf interception and evaporation was determined by separating the rainfall record into independent rainfall events using the statistics module of EPA-SWMM. An inter-event dry period of 6-hours was used to separate events.

This dry period was chosen to best represent the amount of time necessary for wet leaves to dry before being available for new interception. A Microsoft Excel spreadsheet was set up to calculate leaf interception from each of these storm events.

Leaf interception was determined through multiplying a leaf area index of 4.5 and an incremental interception depth of 0.0078 inches. This depth represents the depth of water that can be effectively held by a leaf. The two multiplied together represents the theoretical interception storage of a tree and equals 0.0351inches.

The smaller of total rainfall or potential interception was calculated for each event over the study period to determine actual interception for each event. The total leaf interception was then summed for the study period and expressed as a percentage of total rainfall.

Based on the simulation modeling, the chosen standard tree can intercept 7.26% of the annual rainfall or 3.51 inches. The standard Nashville tree is 30 feet in diameter or 707 square feet of canopy. Thus a tree can intercept 208 cubic feet of rainfall a year or 1,553 gallons.

<u>Volume Removal by Trees - Transpiration</u>
The ability of trees to transpire rainwater in the ground depends on the current climate, the available water in the ground, and the seasonality of the tree's needs. A long term simulation was run using daily rainfall and potential evaporation data for the Nashville area for 1970 through 2006. The ability of the tree to use water was determined by multiplying the potential evaporation by a crop factor (reflecting the demand the tree places on the water and adjusted by month) and a stress factor depending on the availability of the water in the soil.

The crop factor was taken as 1.1 during the growing season and 0.4 during the dormant season. It was interpolated during transition months. The stress factor was taken as 1.0 if the moisture in the soil was equal to the readily available water (RAW) which was estimated at 0.6 times the total available water (TAW). TAW is calculated as the field capacity of the soil minus the wilting point. Sensitivity tests were performed to determine how important each variable was to the total transpiration estimate. The combined total of tree and understory interception (assumed to be half the tree interception value on average) was removed prior to water becoming available to the soil for tree for transpiration.

Based on modeling the total percent of rainfall that could be transpired was 54.8% of the annual rainfall or 26.47 inches. The standard Nashville tree is 30 feet in diameter or 707 square feet of canopy. Thus a tree can transpire about 1,569 cubic feet of rainfall a year or 11,700 gallons.

Table 3.10 shows a summary by basin of the ability of urban trees to remove runoff in excess of current land use. If all of the potential planting sites were taken with urban trees the increase in capture of rainfall volume is estimated to be about 660 million gallons annually.

Per 1,000 square feet urban trees can capture a total of 29.98 inches or 18,690 gallons per year.

Table 3.10--Rainfall Volume Capture by Urban Trees.

Basin	Area		Potential Planting Sites			Capture		
	Basin Area (acres)	No. Planting Sites	Potential New Tree Canopy (acres)	Potential Imperv. Understry (acres)	Interception (mg/year)	Transpiration (mg/year)	Total (mg/year)
1st & Broadway	84	42	0.66	0.20	0.06	0.47	0.54
Benedict Crutche	277	2630	41.1	8.1	3.9	29.6	33.5
Boscobel	230	1485	23.3	5.6	2.2	16.8	19.0
Driftwood	612	4269	66.3	14.4	6.3	47.7	54.0
Ft Nashboro	22	4	0.06	0.04	0.01	0.04	0.05
Kerrigan	3388	19772	310.3	73.9	29.6	223.0	252.6
Schrader	347	2454	38.4	8.6	3.7	27.6	31.3
Van Buren	534	3696	57.7	12.0	5.5	41.5	47.0
Washington	860	6676	105.0	18.3	10.0	75.4	85.4
Washington Sep.	1524	10745	168.3	26.1	16.0	121.0	137.0
TOTALS	7878	51773	811	167	77.3	583.1	660.4

3.6 Structural Control Measures

The infiltration and evapotranspiration of rainfall is nature's primary way of removal of stormwater. Structural control measures use nature's approach, but through enhancements allowing for concentrated storage and eventual infiltration/evapotranspiration they can help to counter the impacts of impervious area.

3.6.1 Overview

This study assessed a broad spectrum of design parameters for three structural control measures to evaluate the theoretical ability of several structural control measures to remove stormwater volume:

- bioinfiltration
- porous pavements (e.g. paver blocks, porous concrete, etc.)
- tree planter boxes

Facts About Stormwater Control Measures:

- ✓ Bioinfiltration, porous pavements, and tree planter boxes were investigated in this study – all have an ability to remove rainfall runoff through infiltration and/or evapotranspiration.
- ✓ Design changes and several demonstration sites to test designs are recommended.
- ✓ There are 1175 acres of parking in the CSS area generating more than 1,500 million gallons/year.
- ✓ Properly designed bioinfiltration can remove more than 80% of the runoff from a parking lot.
- ✓ At lower parking lot to surface area ratios porous pavements (permeable pavements and paver blocks) and tree planter boxes can also attain better than 80% removal.

Long-term simulations were performed in order to account for the full range of possible climatic conditions encountered in Nashville. Hourly rainfall and daily potential evapotranspiration data were acquired from the Nashville ASOS station spanning the years 1971 through 2006 and used for all simulations.

Bioretention cells, porous pavements, and tree planter boxes were all evaluated for runoff volume reduction potential using version 5.0.16 of the EPA-SWMM model. A single, fairly simple model framework was found to properly represent all three practices. A single subcatchment was used to represent the downtown source areas. Ponding on the surface of the source area subcatchment was modeled, as well as evaporation from the ponded water. The source areas were treated as 100% impervious. Runoff from the source areas was determined using the EPA-SWMM procedure for each time step. This runoff was routed to the green infrastructure practices to determine the potential volume reduction for each prototype.

The amount of source area treated by each prototype GI practice was theorized to have a significant impact on performance. This effect was examined by varying the size of the source area subcatchment, while holding the area of the treatment practice constant. This drainage ratio was varied from 0:1 (no source area) to 20:1.

The green infrastructure practices were modelled as a SWMM subcatchment underlain by an aquifer. The GI subcatchment was used to characterize surface ponding, evaporation from the surface, infiltration into the underlying media, and runoff. Water infiltrated by the GI subcatchment was routed to an aquifer to model storage within the media. Water within the aquifer was stored in either the saturated or unsaturated zones, whose interface was modelled to rise or fall as water was added or subtracted from the saturated zone. Evapotranspiration from the aquifer was modelled, using crop coefficients from the literature. Percolation from the saturated zone into the underlying soil was also modelled for a range of percolation rates, since the characteristics of the deep soils in the urban area are not well known. The percolation rates used were 0.01, 0.05, 0.2, 0.5 and 1 in/hr.

3.6.2 Key Considerations

The ability of structural control measures to remove volume balances a number of factors:

- storage capacity and physical characteristics within underground media
- evapotranspiration rate of the surface vegetation (if there is any)
- ratio of impervious area draining to storage control measure surface area
- infiltration rate of the parent material under the stormwater control measure
- care during construction to insure parent soil material is not compacted, ground water table is low enough to allow for infiltration, bedrock is not present, and infiltrated water does not intersect adjacent buildings in a damaging way
- the ability to safely handle flows larger than capacity or to operate if the infiltration capacity should diminish and other design considerations

Several general trends that became apparent during the modeling analysis of bed practices should be noted. Most small storms can be infiltrated by these practices without release of any runoff. During large portions of the year most of the received water goes to increasing the media's water content, but does not lead to saturation and percolation to the deeper soil. Runoff that does occur is most often due to the facility being completely saturated. This saturation condition occurs much more often when underlying soils have a very low percolation rate, and when the ratio of contributing drainage area to facility area is high. These effects can be seen in Figure 3.31 below.
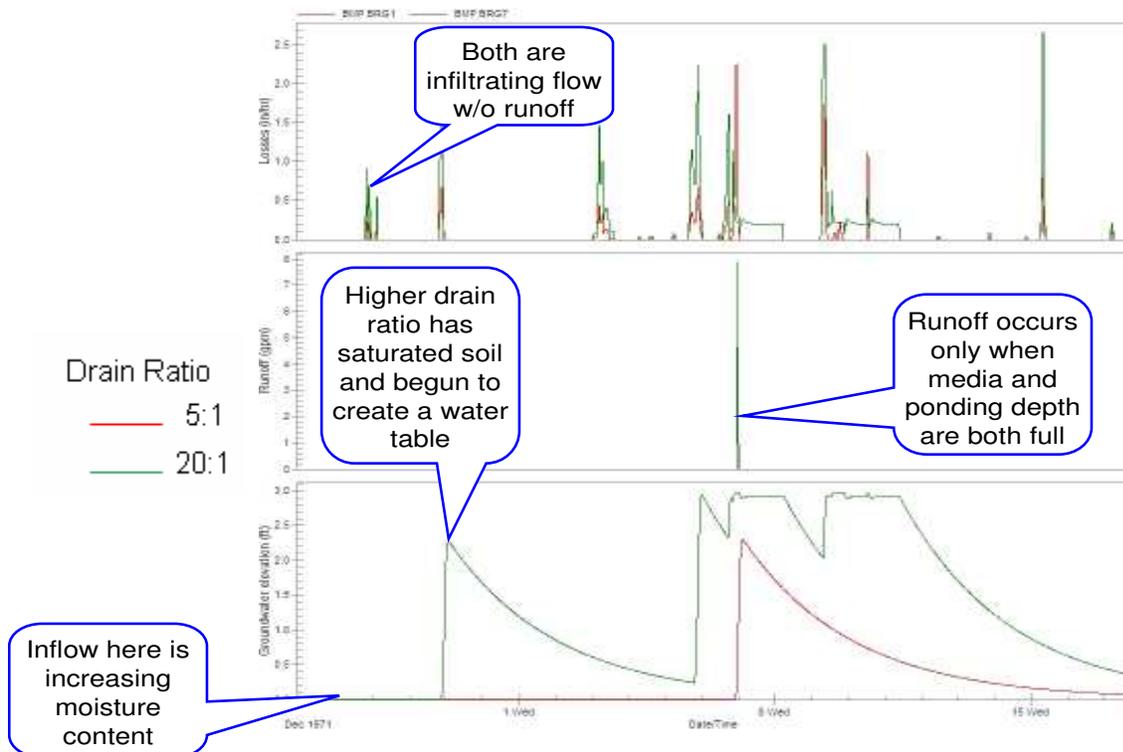
Figure 3.31--Results for 3' Deep Bioretention Cells with Underlying Percolation of 0.2"/hr.

3.6.3 Bioinfiltration

Bioretention systems are shallow, vegetated depressions used to promote absorption and infiltration of stormwater runoff. This management practice is very effective at removing pollutants and reducing runoff volume. Stormwater flows into the bioretention area, ponds on the surface, infiltrates into the soil bed, and is used by plants and trees in the system. It is primarily drained by an underdrain system. It is a flow through device. Examples of bioretention systems are shown along Deaderick Street and the 1700 Charlotte Ave. in Figures 3.32 and 3.33, respectively.

Figure 3.32--Bioretention at Deaderick St.

Bioinfiltration has the same function as bioretention, but is designed to primarily drain through infiltration into the parent material rather than through an underdrain system. Overflows are provided to handle runoff that overwhelms the system or if the infiltration rate should diminish.

Bioinfiltration cells were modelled as 10'x10' areas planted with a mixture of grasses and trees. The planting media was modelled with depths of 1, 2 or 3 feet. Water was modelled to percolate out the bottom of the cells, or run off through an overflow riser any time the ponded depth exceeded 6 inches. Surface evaporation

Figure 3.33—1700 Charlotte Ave. Bioretention.

and evapotranspiration by the trees and grasses were also modelled. Table 3.11 summarizes the setup for the bioretention cell prototypes. Figure 3.34 summarizes modeling results.

You can note a number of things in Figure 3.34:

💧 There is a rapid drop off of performance as the subsurface infiltration rate falls below 0.2 in/hr. Most conventional infiltration-based designs targeting stormwater runoff pollution reduction do not allow for reliance on infiltration below 0.4 to 0.5 in/hr. Volume removal based designs might go somewhat lower (as long as an alternate overflow is provided and construction is done correctly) as the goal is removal of the many smaller storms that can be contained within the soil media. Based on the modeling, 0.2 in/hr appears to be a practical cutoff point.

Table 3.11--Bioinfiltration Cell Model Characteristics (Depth 1, 2, and 3').

Infiltration Parameters		
Suction Head	8,5,4	in
Saturated Conductivity	2.5,8.3,12.3	in/hr
Initial Deficit	0.175	
Ponding Depth	6	in
Storage Parameters		
Porosity	0.45,0.43,0.42	
Wilting Point	0.07,0.05,0.04	
Field Capacity	0.25,0.16,0.13	
Sat. Conductivity	2.5,8.3,12.3	in/hr
Conductivity Slope	8	
Tension Slope	10	
Upper ET Fraction	0.62	
Beginning Moisture Content	0.225	
Depth	1,2 or 3	ft
Starting Water Table Depth	0.25	ft
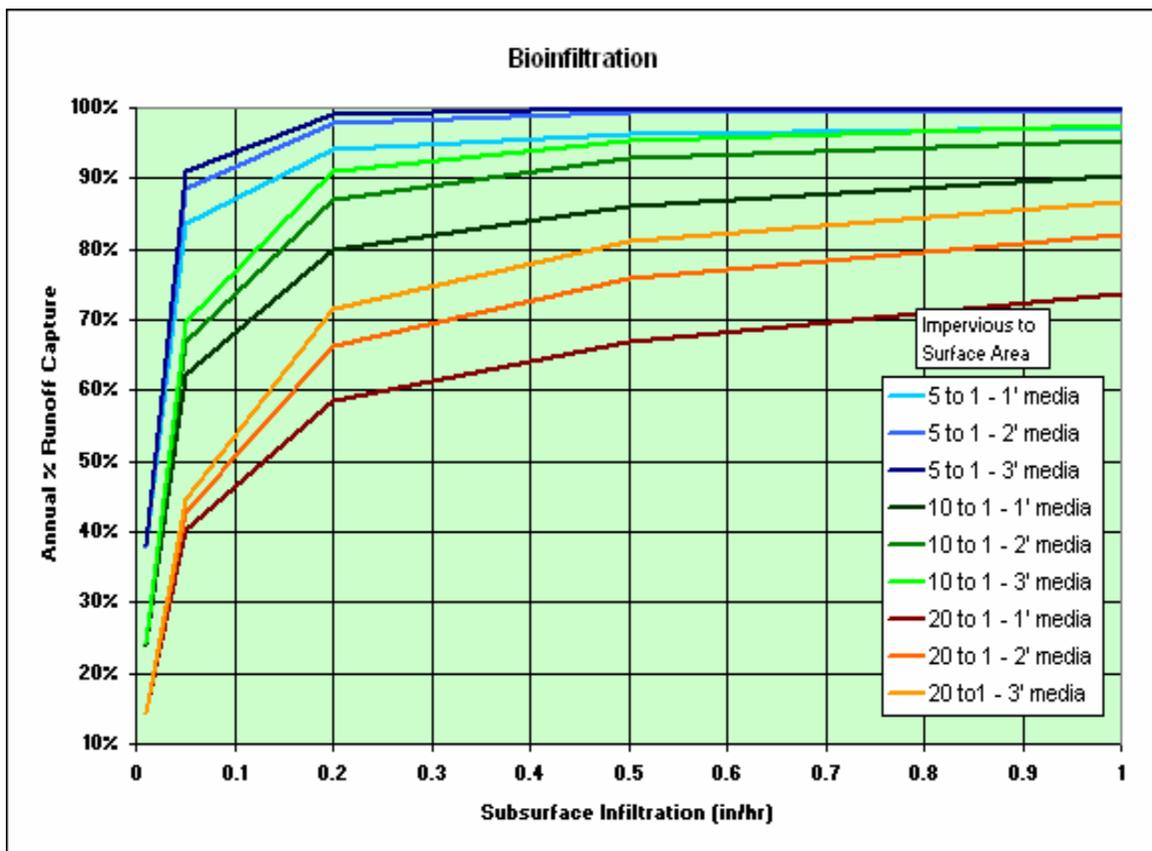
Figure 3.34--Bioinfiltration Modeling Results.

- The <u>percent</u> annual capture of rainfall runoff reduces as the ratio of impervious to pervious increases. However it should be understood that the percent is of a higher runoff, and that the actual total runoff capture may go up.
- The increase in media depth has a more pronounced effect as the ratio of impervious to surface of the bioinfiltration structure goes up. This is to be expected as the demand for usable storage volume in the subsurface media will also go up.
- Increase in media depth for smaller impervious to pervious ratios has less and less effect. For example, at 5:1 increasing the media depth from two to three feet will not materially improve performance.

Figure 3.35 allows for the estimation of annual gallons of runoff removed per hundred square feet of bioinfiltration surface area for various media depths and ratios of impervious to surface area. Note that there is a ceiling where all runoff is removed and that, for example, at 5:1 all the curves collapse at this upper limit regardless of the media depth.
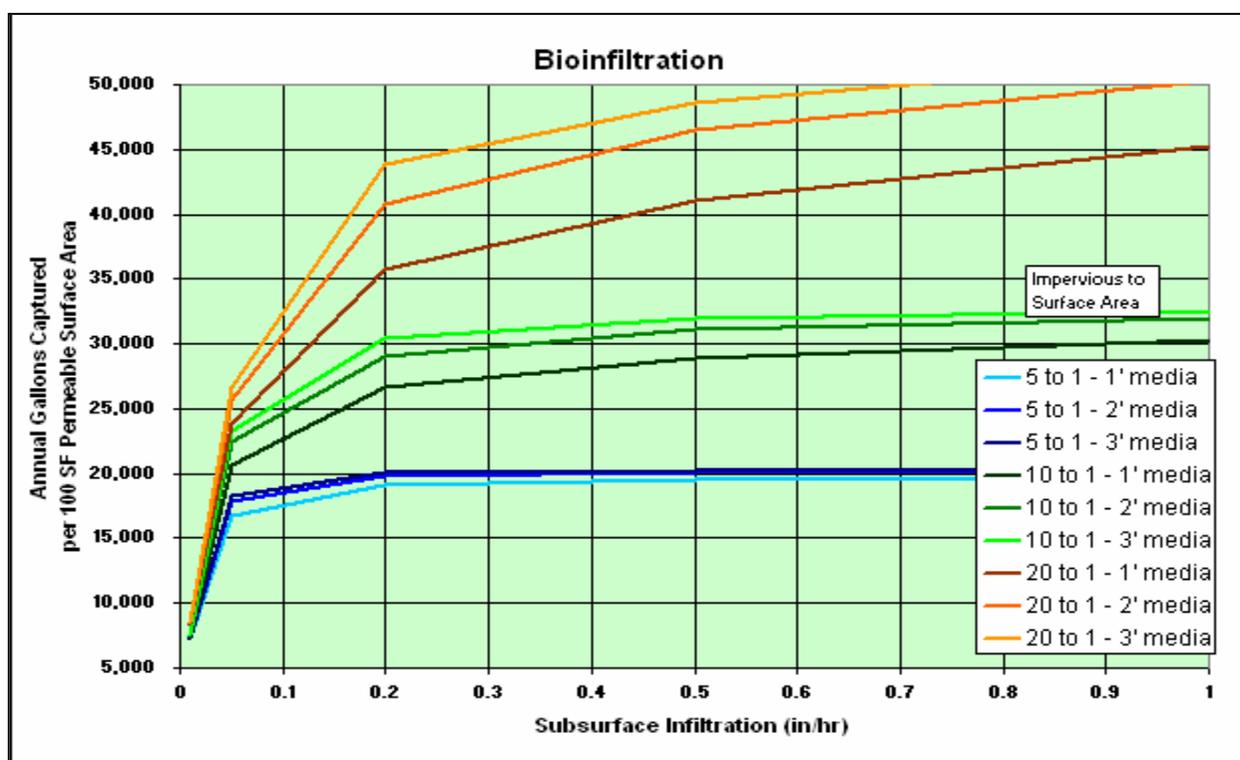
Figure 3.35--Annual Gallons Removed for Bioinfiltration.

3.6.4   Permeable Pavement

As described previously, permeable pavement (pervious pavement, porous surface) provides the structural support of conventional pavement, but allows stormwater to drain directly through the surface into the underlying stone base and soils, thereby reducing stormwater runoff. There are permeable varieties of asphalt, concrete, interlocking pavers and grid systems. Permeable pavements are designed with an open graded stone sub-base that allows water to pass through to the native soil and provides temporary storage. There are different specifications depending on the application. For example, for many paver block applications in Tennessee the standard base is 18 inches consisting of three layers of #2 stone (12-inch), #57 stone (4-inch), and #89 (2-inch).

It is critical that the construction is performed correctly, and especially that permeable concrete or asphalt is mixed and placed as specified. There have been both significant successes and some failures. Figure 3.36 illustrates this. The two images on top are seen as successful. The top left image is the Tennessee Association of Realtors and top right image is Alcoa – Walter Wise site. The lower two applications have experienced some problems with surface clogging (left) and probably a failing or poorly constructed underdrain system (right).

Figure 3.36--Examples of Pervious Concrete.

Permeable pavement areas were modelled as 10'x10' areas of pervious concrete sloped at 1%. The paving was underlain by 2.5 feet of open-graded gravel bed with no underdrain. Ponding up to 0.5-inch was allowed prior to overflow to the conventional drainage system. Evaporation from surface ponding, infiltration into the media, percolation into the underlying soil, and runoff were modelled.

Table 3.12 summarizes the setup for the pervious pavement prototypes. Figure 3.39 summarizes modeling results for annual runoff capture. Figure 3.40 allows for the estimation of annual gallons of runoff removed per hundred square feet of pervious surface area for various

media depths and ratios of impervious to surface area. Note that, as in bioinfiltration, there is a ceiling where all runoff is removed and that, for example, at 5:1 all the curves collapse at this upper limit regardless of the media depth.

Figure 3.37--Permeable Paver Construction St. Johns Church, Knoxville.

Figure 3.38--Permeable Pavers Gatlinburg Hilton Hotel.

Table 3.12--Permeable Pavement Model Characteristics.

Infiltration Parameters		
Suction Head	1.0	in
Saturated Conductivity	250	in/hr
Initial Deficit	0.33	
Ponding Depth	0.5	in
Storage Parameters		
Porosity	0.4	
Wilting Point	0.01	
Field Capacity	0.04	
Sat. Conductivity	250	in/hr
Conductivity Slope	8	
Tension Slope	10	
Upper ET Fraction	0	
Beginning Moisture Content	0.025	
Depth	2.5	ft
Starting Water Table Depth	0.25	ft
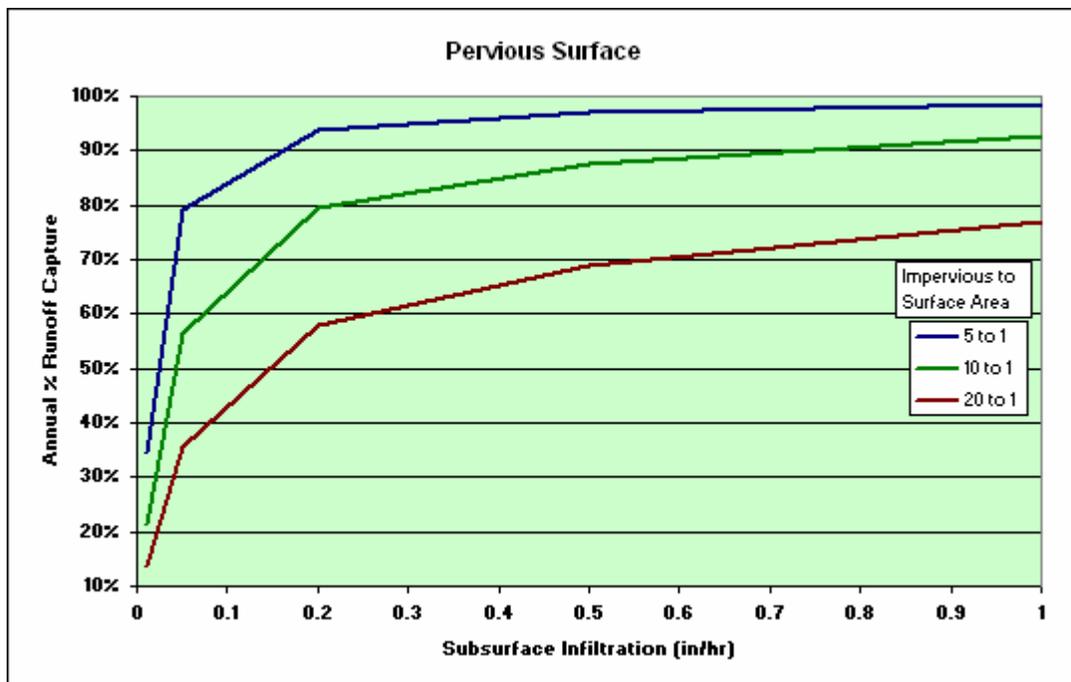
Figure 3.39--Pervious Surface Modeling Results, Media = 2.5' Gravel.
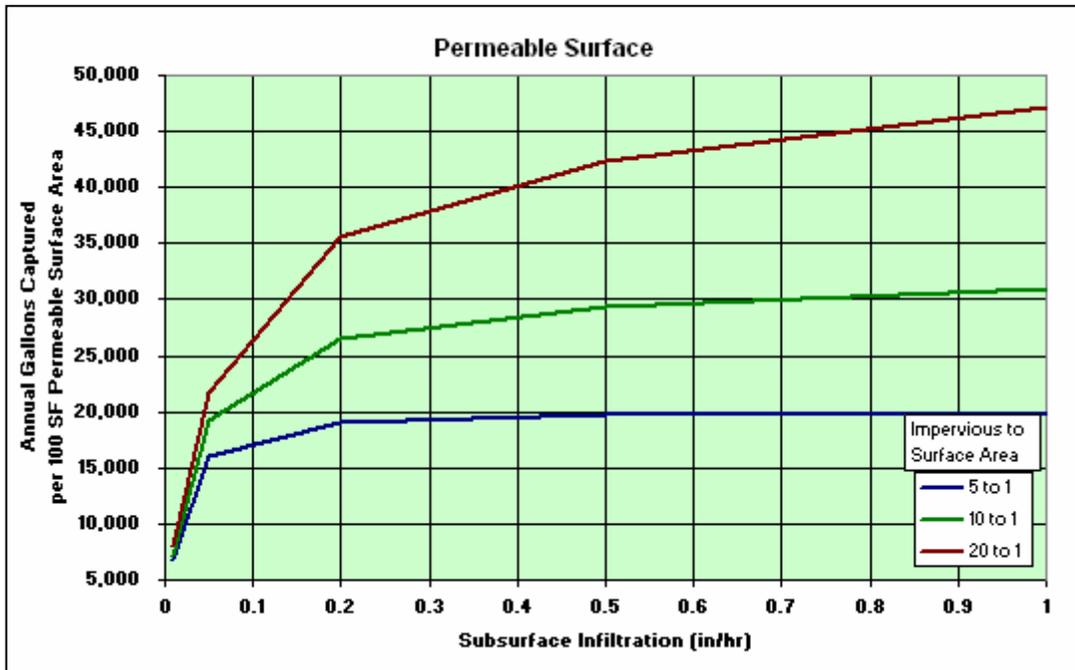
Figure 3.40--Annual Gallons Removed for Pervious Surfaces.

3.6.5   Tree Planter Boxes

As discussed in a previous section, tree planters that are designed to remove stormwater are indistinguishable from conventional tree boxes. There are two types of planter boxes, contained planters and infiltration planters. Contained planters are planter boxes that are placed over impervious surfaces. Figure 3.41 shows two examples.

Figure 3.41--(L) Old Style and New Style Tree Planters.
(R) Trees along Deaderick Street. (courtesy Filterra)

They hold trees, shrubs, and ground cover. Infiltration planters are containers or structures with open bottoms that contain a layer of gravel, soil, and vegetation. They are designed to allow stormwater runoff to temporarily pool on top of the soil and then slowly infiltrate into the ground. Stone, concrete, brick, plastic lumber, or wood can all be used to construct infiltration planters.

Tree planter boxes were modelled as 6'x6' boxes covered with a grate. Note that Metro code recommends ninety square feet minimum of growing media – though some of it can be covered by impervious surface. Each box contained one tree of ~30' crown diameter. The planting media was set 4-inches below the grate and was comprised of the mixture that Metro Nashville currently uses for tree planters and bioretention cells. This mix is made up of 2 parts sand, 1 part topsoil and 1 part organic mulch. The boxes were modeled as 3' deep to represent the depth typically used by Metro Nashville Public Works. Water was modelled to percolate out the bottom of the planter. Water was also modelled to run off any time the water level within the box exceeded the 4-inch grate depth. Evaporation from within the box and evapotranspiration by the tree were modelled as well. Table 3.13 summarizes the setup for the tree planter box prototype.

Table 3.13--Tree Planter Box Model Characteristics.

Infiltration Parameters		
Suction Head	8	in
Saturated Conductivity	2.5	in/hr
Initial Deficit	0.175	
Ponding Depth	4	in
Storage Parameters		
Porosity	0.45	
Wilting Point	0.07	
Field Capacity	0.25	
Sat. Conductivity	2.5	in/hr
Conductivity Slope	8	
Tension Slope	10	
Upper ET Fraction	0.70	
Beginning Moisture Content	0.225	
Depth	3	ft
Starting Water Table Depth	0.25	ft

Figure 3.42 shows the results of the modeling analysis on an annual percent rainfall capture basis. Figure 3.43 allows for the estimation of annual gallons of runoff removed per six foot by six foot (36 sq.ft.) of planter box surface area for various ratios of impervious area draining to the box.
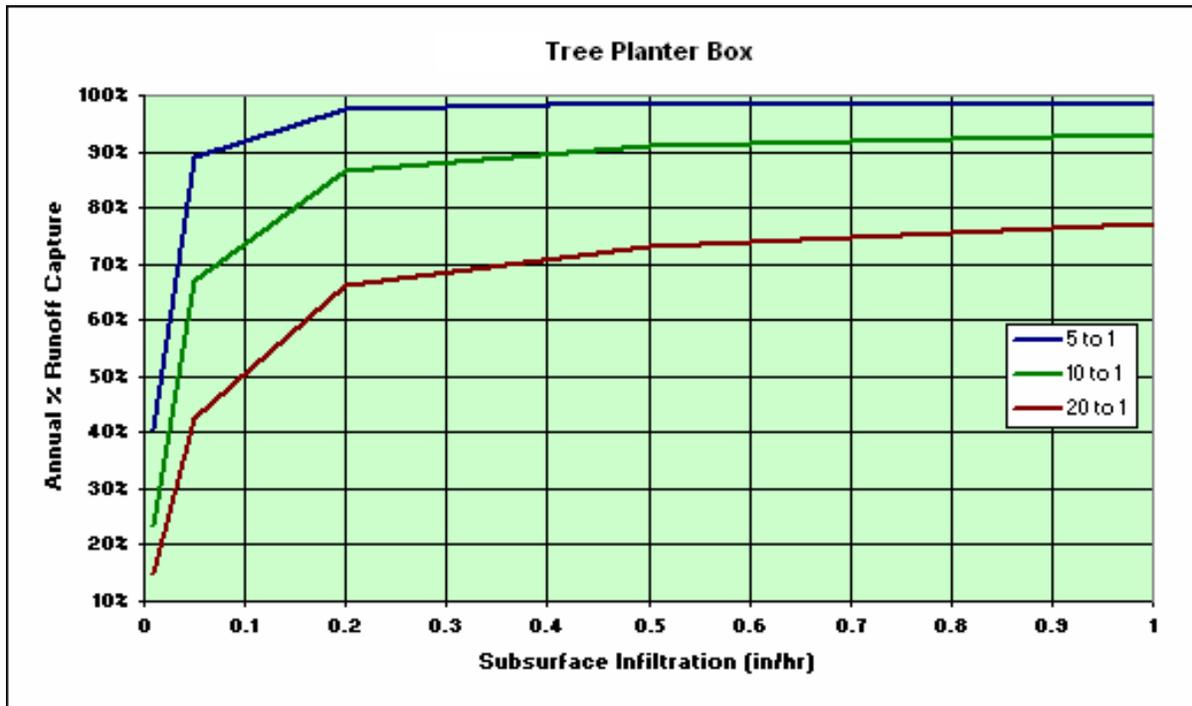
Figure 3.42--Tree Planter Box Modeling Results.
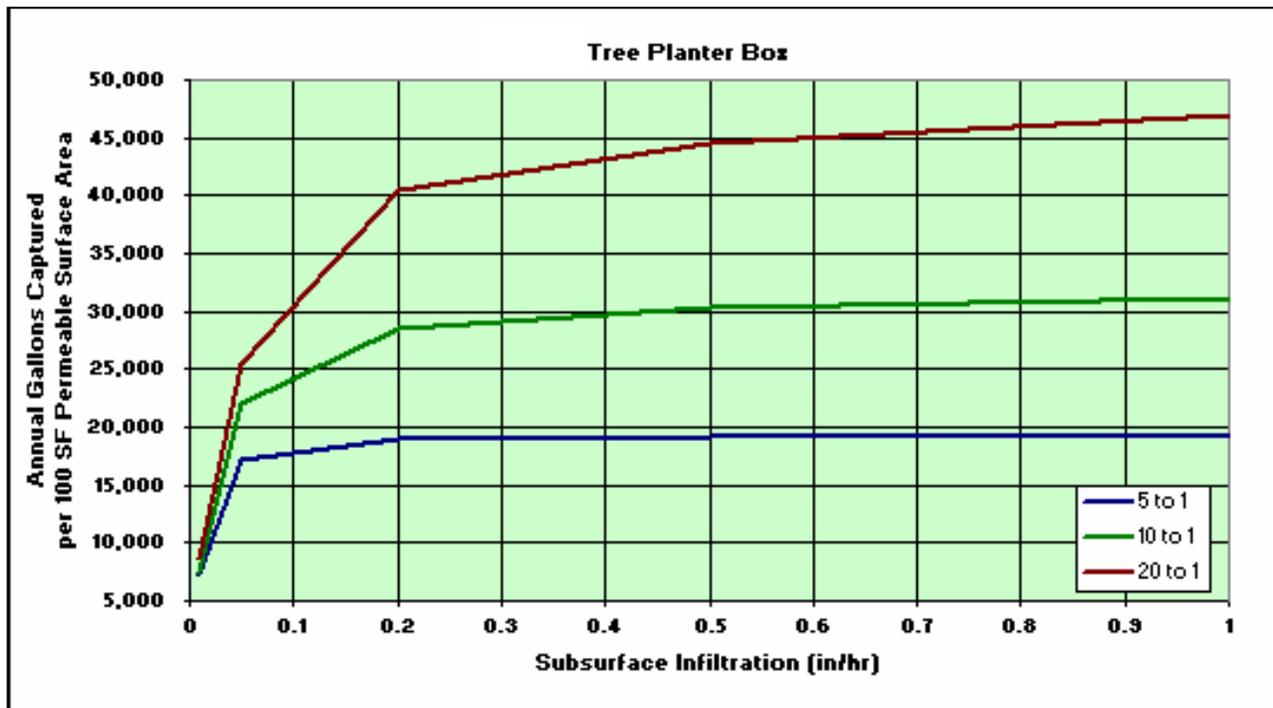
Figure 3.43--Annual Gallons Removed for 6' by 6' Planter Boxes.

3.6.6 CSS Area Analysis

No detailed attempt has been made to assess an overall capture of stormwater volume using stormwater control measures and estimating "actual" retrofit percentages based on analysis of roadways and parking. However, as an illustration the ability of bioinfiltration to capture runoff was done. Table 3.14 gives parking lot impervious information for each of the basins in the CSS area. Figure 3.44 illustrates this coverage for the Kerrigan Basin.

Table 3.14--Assessment of Bioinfiltration Volume Removal in CSS.

Basin	Area	Parking Lots		Bioinfiltration Volume Capture					
				Control Surface Area Needed 1000SF			Million Gallons Captured/Year		
	Basin Area (acres)	Parking (acres)	# Parking Lots > 1,000 SF	5:01	10:01	20:01	5:01	10:01	20:01
1st & Broadway	84	13.0	64	113	57	28	24	18	13
Benedict Crutcher	277	37.2	74	324	162	81	67	51	37
Boscobel	230	6.3	42	55	28	14	12	9	6
Driftwood	612	119.4	469	1,041	520	260	216	165	119
Ft Nashboro	22	1.9	6	16	8	4	3	3	2
Kerrigan	3388	640.0	2781	5,576	2,788	1,394	1160	884	636
Schrader	347	18.5	114	161	81	40	34	26	18
Van Buren	534	100.9	240	879	440	220	183	139	100
Washington	860	114.1	395	994	497	248	207	157	113
Washington Sep.	1524	124.1	359	1,081	540	270	225	171	123
TOTALS	7878	1175	4544	10,240	5,120	2,560	2130	1623	1167

Almost 15% of the total CSS area is covered by parking lots. Another 14% is covered by roads. Thus transportation support infrastructure covers about 29% of the total land area in the CSS – all at 100% impervious. In round numbers, Table 3.14 shows that bioinfiltration can capture a high proportion of the runoff from these areas. From Figure 3.34, the percent captured ranges from 68% at 20:1 impervious to pervious ratio to 98% for a 5:1 ratio, leading to an ability to remove between 1,167 and 2,130 million gallons per year from the CSS system if all parking areas were retrofit. This discounts the potential that some of this infiltrated water would return to the system as infiltration and inflow (I&I).
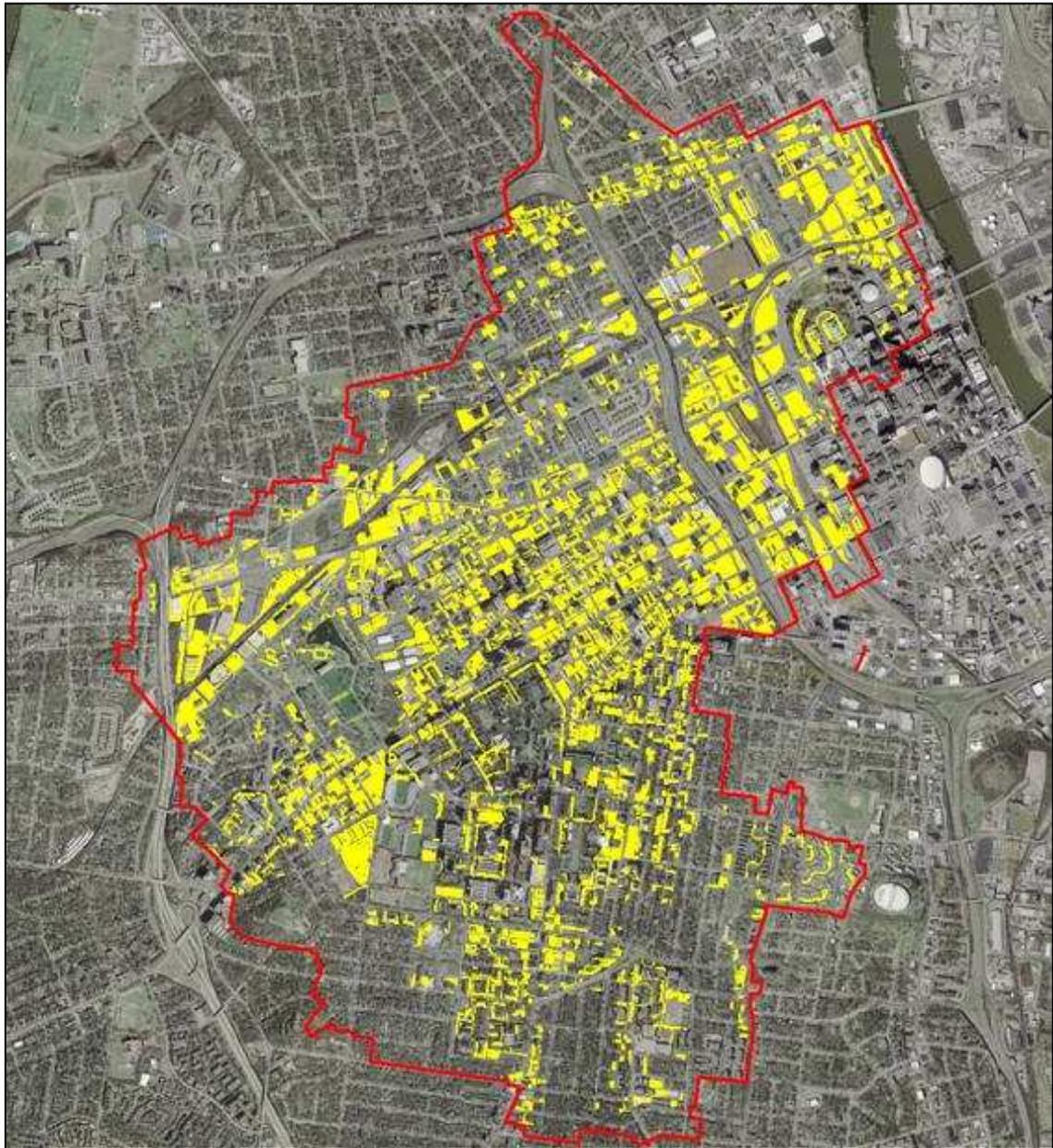
Figure 3.44 Parking Lots in the Kerrigan Basin

3.7 Study Area Scenarios

3.7.1 Scenario Development

This section will summarize volume removal capabilities and develop an ability to quickly develop removal scenarios given the realities on the ground. Obviously, any estimation of the actual development and code change scenarios is only a guess. The purpose of this is to provide design tools and factors to allow for quick though approximate assessment of the combination of key green infrastructure tools in the CSS area.

Volume removal factors will be developed, ranges of application examined, and all will be applied, as an example, to the Van Buren Basin.

3.7.2 Green Infrastructure Volume Removal Factors

Typical designs will be chosen for each of the key green infrastructure components to allow for broad analysis of scenarios. Use of other options would change the outcome. Use of typical values and designs will give an "average" sense of ability to remove volume.

Table 3.15 gives a convenient summary of the relative ability of green infrastructure practices in Nashville to remove rainfall from the CSS system per 1,000 square feet of drainage, canopy or roof area as appropriate. Specific assumptions about each practice application are given below the Table. Note that the Table is only representative and most of the practices have a range of sizing options.

Average rainfall in Nashville is 48.3 inches. All values are expressed in terms of percent of average rainfall and total gallons per unit area per year. Specific assumptions are given below. Calculation of removal rates for a different set of design parameters can be done simply through reference to the discussion in each section.

Table 3.15—General Rainfall Volume Removal Summary.

Practice	Capture per 1,000 SF Drainage, Canopy or Roof Area	
	% of Annual Runoff	Gallons per Year
RW Harvest - Cistern	72%	17,300
RW Harvest - Barrel	18%	4,300
Green Roof	55%	16,600
Urban Trees	62%	18,700
Bioinfiltration	90%	24,400
Permeable Surface	83%	22,500
Planter Box	89%	24,100

- ⬥ RW Harvest – Cistern: 600 gal cistern, demand is set equal to the runoff, 0.8 rooftop runoff efficiency coefficient
- ⬥ RW Harvest – Barrel: 48 hour drain time, one barrel, 0.8 rooftop runoff efficiency coefficient
- ⬥ Green Roof: 75% of rooftop available for green roof, 4-inch media depth, extensive roof

- Urban Trees: only tree canopy area, no runoff to the tree, 30' diameter tree canopy and capture area under the tree, both interception and transpiration, interception in the understory is equal to half the tree interception and is removed prior to moisture becoming available to the tree to transpire
- Bioinfiltration: 10:1 impervious to surface area, 2' media depth, 0.3 in/hr parent material infiltration, 0.9 impervious area runoff coefficient
- Permeable Surface: 10:1 impervious to surface area, 2.5' gravel media depth, 0.3 in/hr parent material infiltration, 0.9 impervious area runoff coefficient
- Planter Box: 10:1 impervious to surface area, 3' media depth, 0.3 in/hr parent material infiltration, 0.9 impervious area runoff coefficient

3.7.3   Example Application to Van Buren Basin

Van Buren basin is depicted in Figure 3.45. It will be used for this example application of the factor data. Specific assumptions on ability to employ green infrastructure are based on brief analysis of the land use, CSO characteristics and other factors, and are for illustration purposes only.

Figure 3.45—Impervious Area in the Van Buren CSS Basin.

Van Buren basin is 534 acres of which 49.6% is impervious. Table 3.1 gives basic information on land use, Table 3.2 gives the types of impervious area by total, and Table 3.3 gives soils information. It is just north of downtown and is adjacent to the Cumberland River making it a

critical target for both flow and direct runoff reduction. The nature of the overflows to the Cumberland makes it potentially sensitive to even small volume reductions.

Other key characteristics are:

- 68 acres of roadway
- 96 acres of building footprint of which 51 buildings totaling 11.2 acres have flat roofs
- 240 parking lots greater than 1,000 square feet totaling 101 acres
- 3,696 potential tree planting sites totaling 57.7 acres
- 458 residential structures

Three options will be assessed – a low growth option (L), a moderate growth option (M), and a "green build out" option (GBO). Each option will be based on a percent of potential green infrastructure application. Volumes are approximate and meant to demonstrate the scale of green infrastructure's impact. The low level for all applications was taken at 5% of the total available capacity. The medium was set at 25% of capacity. The green build out was set at 100% of capacity.

Table 3.16 gives a summary for all green infrastructure practices. The total removals should not be added as there is some duplication. That is for example, rooftops can be treated with a number of practices. Averages were taken where more than one practice may apply.

About 700 million gallons of rain falls on the Van Buren basin annually. Based on a simple rainfall-runoff calculation the basin probably has between 350 and 500 million gallons of runoff annually. The rest may fall on or flow onto grassy areas (run-on) and be absorbed into the soil.

Based on this analysis and assumptions the following total rainfall runoff removals using Green Infrastructure could be achieved:

- 5% of green infrastructure capacity employed – 19.9 million gallons annually
- 25% of green infrastructure capacity employed – 99.7 million gallons annually
- 100% of green infrastructure capacity employed – 399 million gallons annually

Some of this volume would have been captured through run on to the grassy areas and thus is redundant. Some of this capture would have been evaporated from impervious surfaces. A significant portion is in addition to the grassy area and impervious surface evaporation capture. Better estimates could only be derived through detailed modeling.

Table 3.16—Example Application to the Van Buren Basin.

Practice	Capture per 1,000 SF (Gallons per Year)	Roadway			Flat Roof			Other Rooftops			Parking			Tree sites			Res. Structures		
		L	M	GBO	L	M	GBO	L	M	GBO	L	M	GBO	L	M	GBO	L	M	GBO
RV Harvest - Cistern	17,300				0.4	2.1	8.4	3.2	16.0	63.9									
RV Harvest - Barrel	4,300				0.4	2.0	8.1										4.3	21.4	85.8
Green Roof	16,600																		
Urban Trees	18,700													2.4	11.8	47.0			
Bioinfiltration	24,400	3.6	18.1	72.3	0.6	3.0	11.9	4.5	22.5	90.1	5.4	26.8	107.3						
Permeable Surface	22,500	3.3	16.7	66.6	0.5	2.7	11.0	4.2	20.8	83.1	4.9	24.7	99.0						
Planter Box	24,100	3.6	17.8	71.4	0.6	2.9	11.8	4.5	22.3	89.0	5.3	26.5	106.0						

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4.   Green Infrastructure Project Selection and Design

This section discusses the identification of existing Green Infrastructure projects in Nashville and the selection and preliminary concept design of six Green Infrastructure projects in the CSS area.

4.1   Existing Low Impact Development

To provide a common point of understanding among all parties for this process and to provide local examples of the best management practices discussed throughout this study, the design team identified existing low impact development (LID) techniques within Metro-Davidson County. LID is functionally equivalent to Green Infrastructure. Approximately 50 sites were identified and the best management practices they incorporated were included in a project matrix (Table 4.1). This data was provided in GIS format and will allow future additions by the Metro Water Services (MWS) staff. An excerpt of this data is provided in Figure 4.1 showing the locations of low impact developments in the vicinity of the CSS area Master Planning District. A project data sheet format was also created so that a brief project description and summary of best management practices can be accessed from the GIS database.

Figures 4.2 through 4.7 are provided as examples of low impact development techniques currently used in Metro Nashville.
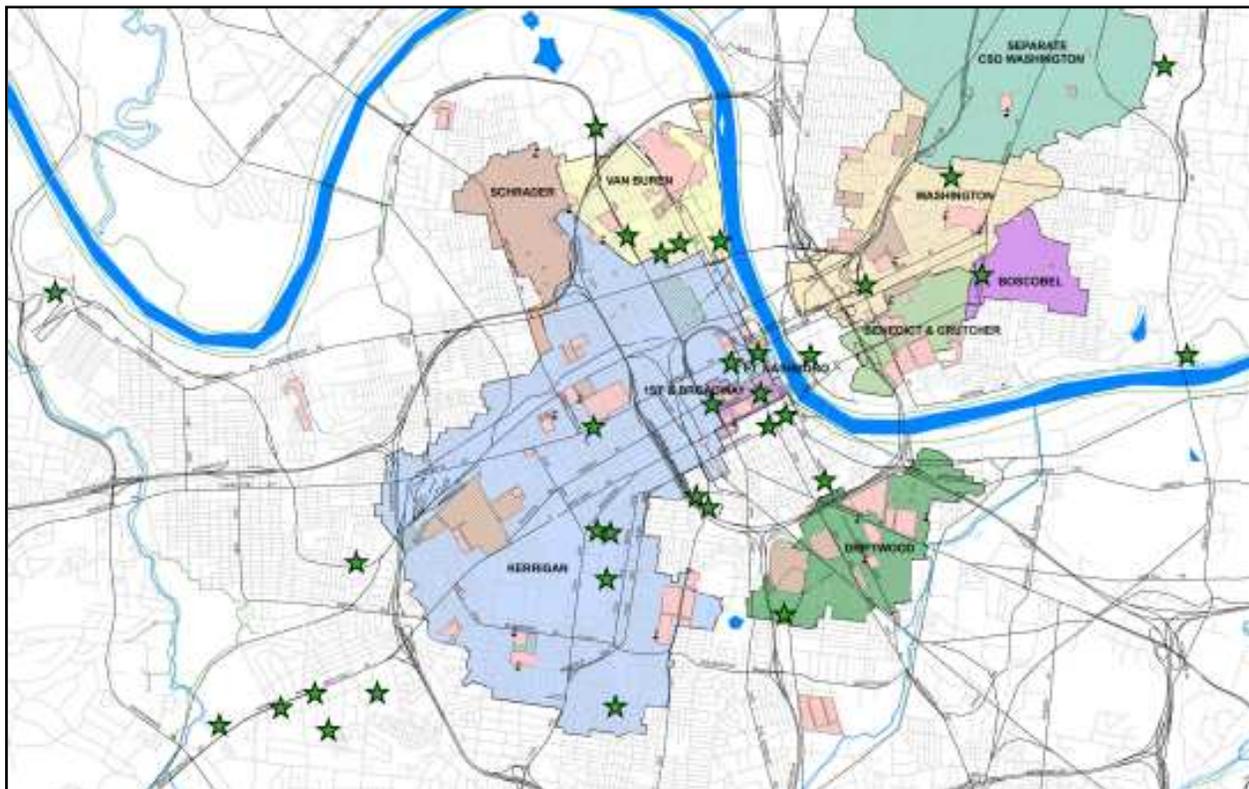

Figure 4.1–-Location of Existing Low Impact Developments.

Table 4.1—List of Identified Low Impact Developments.

Project	Address	Within CSS Area	Water Harvesting	Constructed Wetland	BioRetention Areas	Water Quality Swales	Green Roof	Infiltration Trench	Permeable Pavement	Project Notes
1700 Charlotte	1700 Charlotte Avenue	x			x				x	Bioswales in parking lot
5th and Main	501 Main Street	x					x			Green Roof - Extensive
Adelicia	900 20th Avenue South	x					x			Green Roof - Semi-Intensive
AT&T Building/ Plaza	333 Commerce Street	x					x			Green Roof - Intensive
Avenue Bank	Green Hills - 3823 Cleghorn Dr.								x	
Beaman Park Nature Center	5911 Old Hickory Blvd								x	
Bells Bend Nature Center	4187 Old Hickory Blvd								x	
Carden Avenue Rain Garden	Carden Avenue (Whitland Neighborhood)				x					
Deaderick Street		x			x				x	Green Street bioswales/ Pervious Concrete
Dorset Park (GWP)	Granny White Pike				x					Bio-retention areas
Ellington Agricultural Campus	440 Hogan Rd.				x	x				Bioswales/ Rain Gardens
Freeman Webb	3810 Bedford Avenue						x			Green Roof - Extensive/Semi-Intensive
Friendship Christian School	5400 Coles Ferry Pike								x	
Global Motorsports	Brentwood - 7116 Moore's Ln.								x	
Green Hills YMCA	Green Hills - 4041 Hillsboro Circle								x	
Hill Center - Belle Meade	4340 Harding Pike		x		x	x				Bioswales, Water harvesting
Hill Center - Green Hills	4039 Hillsboro Pike		x			x				Bioswales, Water harvesting
Hilton/ Gateway Park	121 4th Avenue South						x			Green Roof - Intensive
Howard School (Metro)	700 Second Avenue South					x			x	Pervious asphalt and WQ swales along Lindsley
Javanco/ Mercury View	401-501 12th Ave South				x				x	Washed Aggregate Stone
Martin Corner 3	200 11th Street (East Nashville)	x			x				x	
Morgan Park Place	707 Monroe Street	x			x				x	Porous Concrete
Music Row Parking Garage	Music Row								x	
Nashville Nissan	2030 Rosa Parks Blvd								x	
Nashville Opera	Sylvan Park - 3622 Redmon St.								x	
Nashville Skyline	3460 Dickerson Pike								x	
Neuhoff	1300 Adams Street	x					x			
NFL Stadium									x	Reinforced Turf paving
Pilot Gas Station	6418 Centennial Blvd								x	
Pinnacle at Symphony Place	150 3rd Avenue South						x			Green Roof - Extensive/Semi-Intensive
Private Residence	Germantown	x							x	Parking Area
Private Residence	4443 East Brookfield, Belle Meade								x	
Public Square	One Public Square	x	x				x			Green Roof - Intensive
Shelby Bottoms Nature Center	1900 Davidson Street						x			Green Roof - Extensive
South Inglewood Park	East Nashville - 1625 Rebecca Ave.								x	
Southgate	3821 West End Avenue				x					Rain Garden/ Bioswale
Tennessee Assoc. of Realtors	901 19th Avenue South	x			x				x	Pervious Concrete/ Bioretention
Terrazzo	12th and Division						x			Green Roof - Extensive
TN Concrete Assoc. Offices	705 Fort Negley Court	x							x	
Troutt Theater	2100 Belmont Avenue	x							x	Parking Lot
Vanderbilt 100 Oaks	719 Thompson Lane				x	x				Bioswales in parking lot
Vanderbilt Student Commons	230 Appleton Place	x			x				x	
Walmart Supercenter	Nolensville Rd and OHB								x	
Werthan Mills	1400 8th Avenue North	x					x			Green Roof - Extensive
West Eastland Townhomes	West Eastland and McFerrin	x			x					Rain Gardens
West End Middle School	3529 West End Ave				x					Rain Garden
West View Lofts	179 8th Avenue North	x					x			Green Roof - Intensive

Figure 4.2—Existing Bioswale at the Hill Center Belle Meade.

Figure 4.3—Porous concrete and Bioretention Area at Morgan Park Place.

Figure 4.4—Existing Pervious Concrete Parking at TN Association of Realtors.

Figure 4.5—Existing Bioretention Areas Along Deaderick Street.

Figure 4.6—Porous concrete at Avenue Bank in Green Hills

Figure 4.7—Existing Green Roof at the Pinnacle at Symphony Place.

4.2 Development of Proposed Projects

4.2.1 Goals and Objectives

The goal of Green Infrastructure projects associated with this Master Plan is to reduce stormwater inflows to the combined sewer system (CSS) and to encourage stewardship of water resources.

The following general objectives were established to guide the selection of projects for design and implementation:

- Encourage the use of low impact development to achieve improved water quality and infiltration within the CSS.
- Reduce the use of potable water for non-potable needs, such as irrigation.
- Allow Metro to lead the way for demonstrating the use of Low Impact Development (LID) for a variety of best management practices on Metro owned property.
- Educate the development community and the public by locating pilot projects on sites that are publicly visible or accessible.
- Select projects where the selected best management practices offer multiple sustainability benefits.

> **Project Development Process:**
>
> ✓ Research existing use of Green Infrastructure measures in Nashville.
> ✓ Consult with Metro Departments on stormwater problem areas and potential Green Infrastructure measures.
> ✓ Review stormwater problem areas and potential Green Infrastructure measures with Technical Advisory Committee.
> ✓ Develop list of potential project sites and proposed Green Infrastructure measures for each site.
> ✓ Review proposed project sites with Technical Advisory Committee and establish priorities.
> ✓ Develop conceptual designs for priority projects.
> ✓ Brief affected Departments on proposed projects.

More specific screening criteria were created to help evaluate potential sites, and are discussed below.

4.2.2 Multi-Department Coordination

In order to evaluate the CSS basins and the potentials for improvement, the design team first conducted a series of interviews with primary Metro Departments in order to assess current problem areas identified with flooding or overflow and potential project sites where capital projects are intended in the near future. The Departments who participated in interviews were Metro Planning Department, Metro Water Services, Metro Public Works, and the Metropolitan Development and Housing Agency. Each department provided their current problem areas and potentials within the CSS as site addresses and these were mapped in GIS.

As a part of this process, Metro Water Services also identified which CSS basins were most critical due to historical issues with stormwater capacity. These were identified as Boscobel, 1st and Broadway, Benedict and Crutcher and Van Buren. They also identified the Boscobel and 1st and Broadway basins as most critical for volume reduction.

Properties owned by the Metropolitan Government were identified within the Master Planning District and an overlay was created in order to analyze this data for potential locations of pilot projects (Figure 4.8).
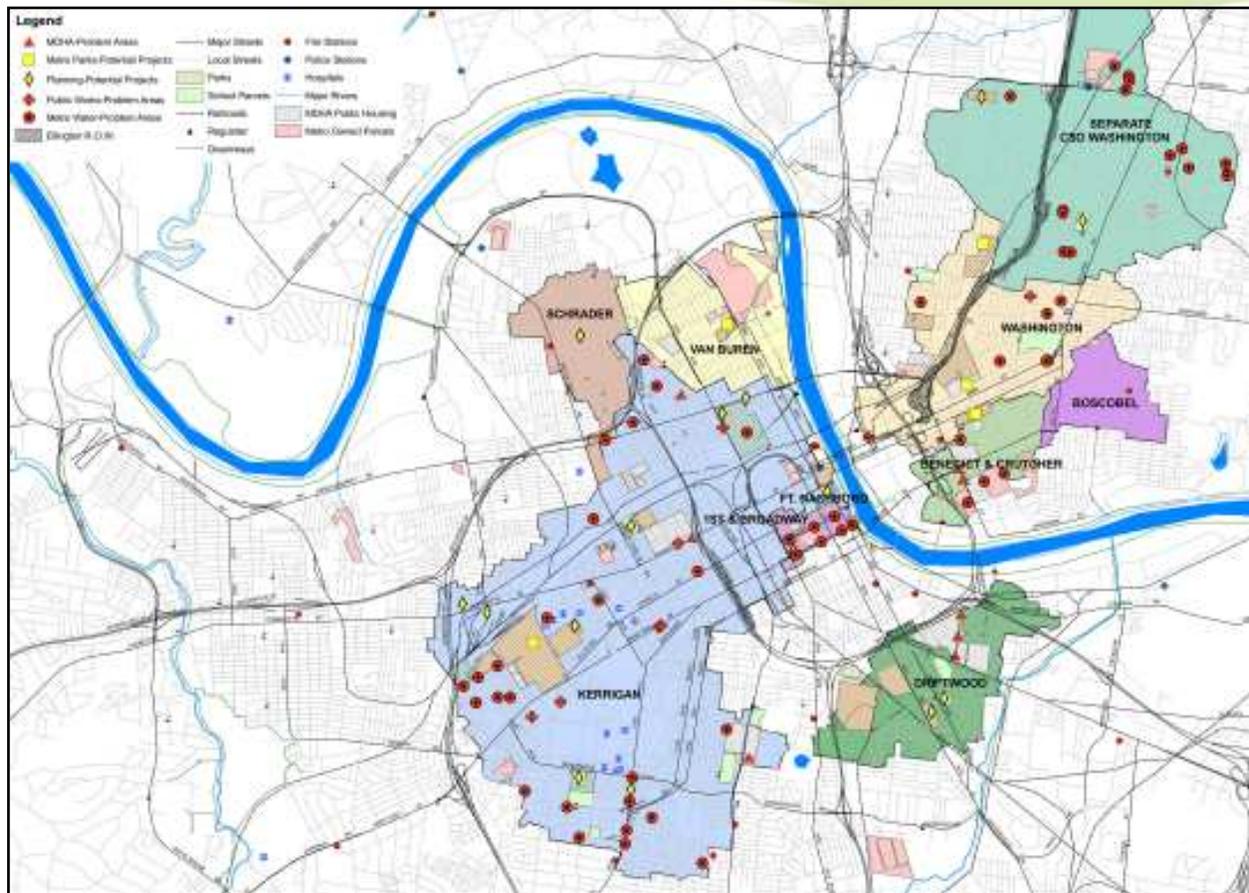
Figure 4.8 – Metro Identified CSO Problem Areas and Project Potentials

4.2.3 Project Screening

In the overview of the CSS basins, the team evaluated several specific criteria for the potential effectiveness of Green Infrastructure applications. These criteria are listed below:

- ♦ MWS identified the availability of Metro-owned land within basins as critical for public benefit and volume.
- ♦ Each site was also evaluated based on its proximity to a previously identified problem area.
- ♦ The CSS incorporates areas in north, west and east Nashville; a geographic distribution of pilot projects in the CSS was important.
- ♦ Pilot projects were selected which could demonstrate a number of different low impact development solutions utilizing current recommended best management practices.
- ♦ Where the demonstration of best management practices could provide added sustainability benefit beyond stormwater, such as reducing heating or cooling cost, reduced potable water consumption or public education benefit, the rating of the project was higher.
- ♦ Site specific conditions, such as drainage patterns and complexity of implementation were also factors in evaluation.

Based on the criteria, the team developed an initial list of 21 potential projects. Each site received a cursory review using aerial photography, Metro GIS and a site visit for evaluation of site specific conditions. There was a discussion of these issues in the Technical Advisory Committee meeting in July 2009. Through that evaluation, the initial list was narrowed to a list of 10 sites. After additional development and analysis of concept plans for each of the 10 sites, a final list of six priority projects was developed as listed in Table 4.2 and displayed in Figure 4.9.

Table 4.2 –Project Evaluation Criteria Matrix.

Top 10 List	Basin	Property	Metro owned property?	Agency Ownership
1	Washington	943 W. Eastland/ Alley/ Private Lot Incentives	X	Private / MPW alley
2	1st & Broadway	Hume Fogg School		MNPS
3	Kerrigan	Nashville Farmer's Market		Farmer's Market
4	Kerrigan	Parthenon Towers		MDHA
5	Kerrigan	Metro Parks Administrative Facility		MP
6	Benedict & Crutcher	Sheriff's Office and Public Works complex		MPW

The six priority projects represent four of the CSO districts. One project each is represented in the 1st and Broadway (downtown), Benedict and Crutcher (East Nashville), and the Washington district (East Nashville). Three projects are located in the largest CSO district, the Kerrigan district that incorporates most of downtown and portions of North Nashville and West Nashville. All sites are located immediately adjacent to identified problem areas.
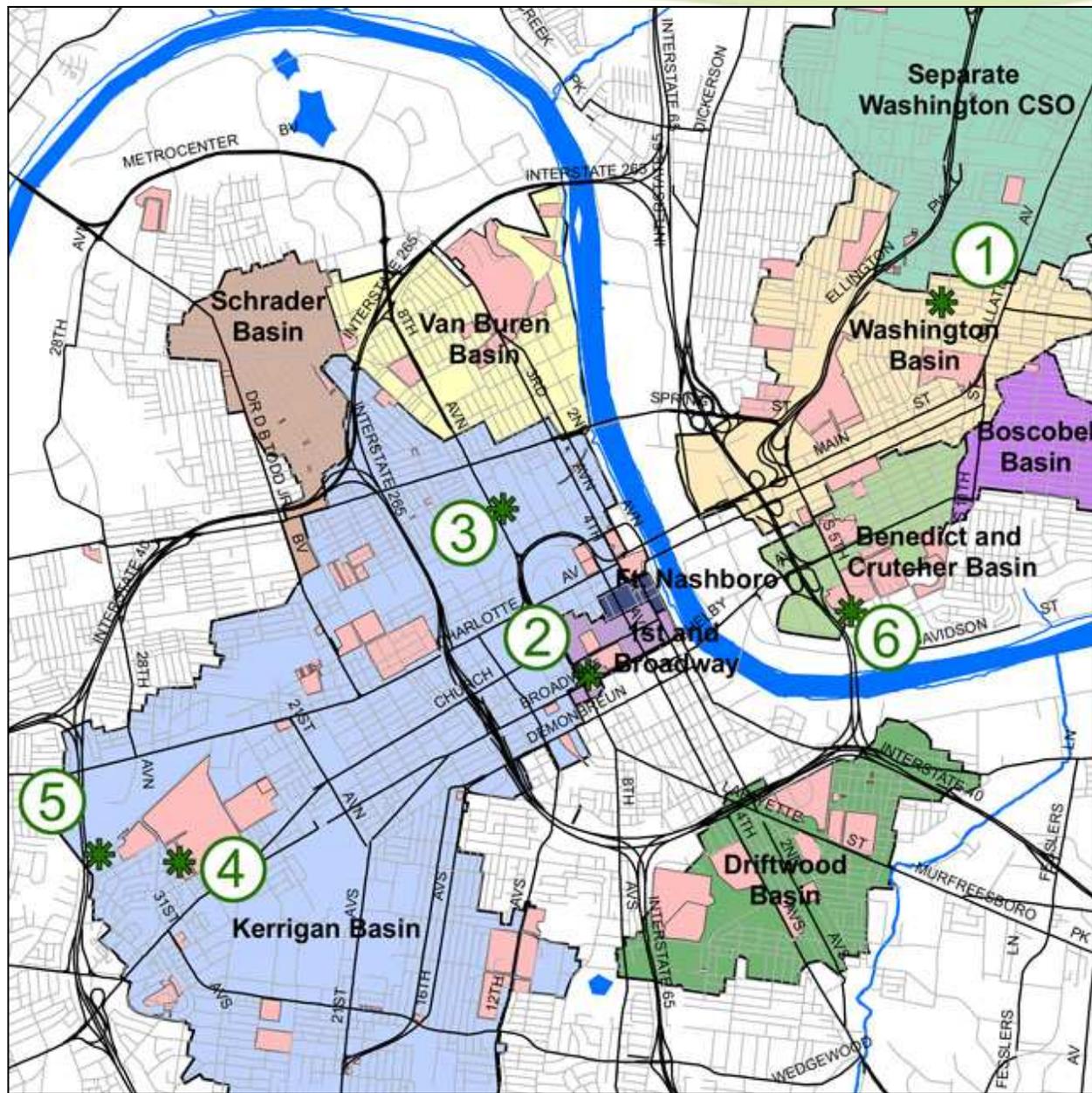
Figure 4.9–-Location of Selected Projects.

4.3   Selected Projects for Implementation

4.3.1   Project 1 - West Eastland Avenue

CSS Basin. Washington Basin.

Council District. District 5.

Location. East Nashville, west of Gallatin Ave. in the vicinity of West Eastland Ave. and Chicamauga Ave. (Figure 4.10).
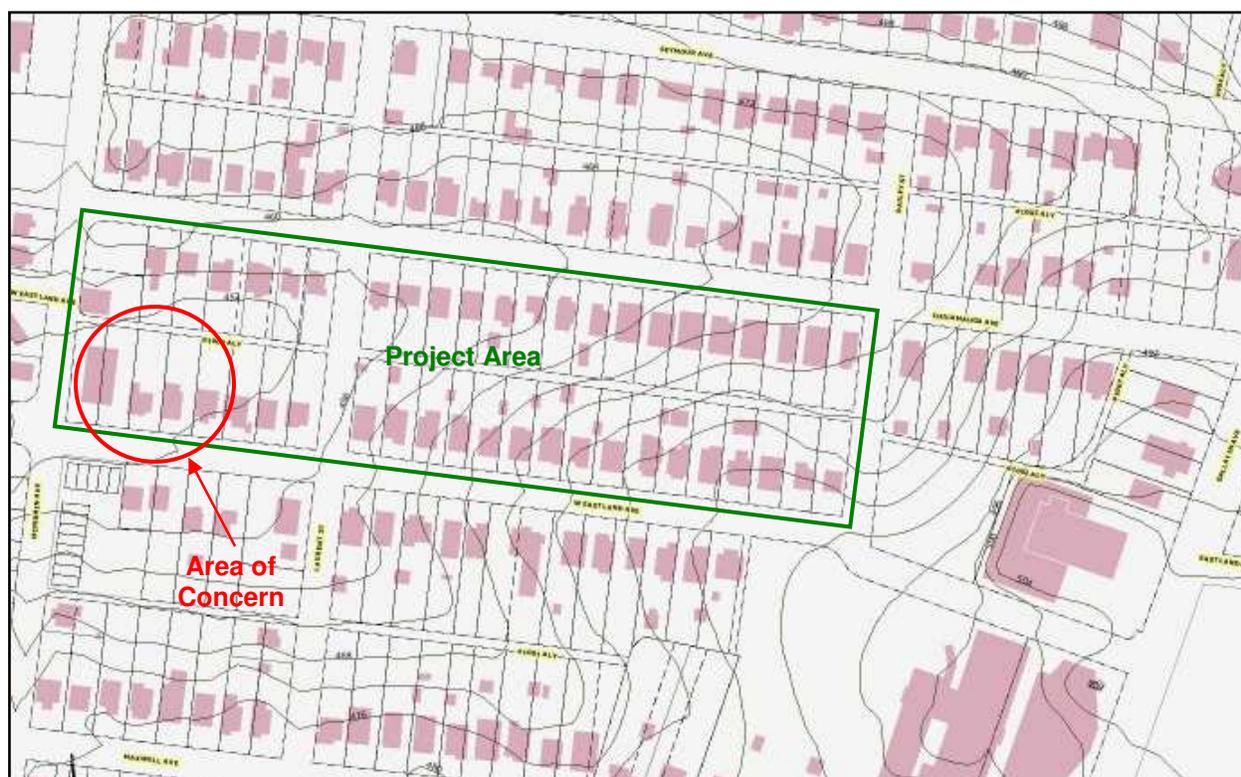
Figure 4.10—Project 1 Location Map.

Problem Statement. Metro Water Services and Metro Public Works both identified this area as one having a persistent drainage problem that results in frequent phone calls and service requests. Specifically, there is more stormwater runoff conveyed to the alley between West Eastland Avenue and Chicamauga Avenue than the drainage system(s) can handle. The contributing drainage area for this project is approximately 85.5 acres.

Project Goal. The goal of the project is to intercept stormwater runoff through the use of Green Infrastructure before the runoff enters the CSS and before the runoff reaches the alley and results in flooding in the identified area of concern.

Proposed Green Infrastructure Measures. The conceptual design for this site is presented in Figure 4.11. Metro right of way widths allow for incorporation of a variety of pervious and infiltration best management practices. A number of Green Infrastructure measures are proposed in the project area including:

- bioswales along Chicamauga Ave., West Eastland Ave., and Bailey St.;
- parallel parking using pervious concrete along Chicamauga Ave. and Bailey St.;
- pervious pavers in the alley between Chicamauga Ave. and West Eastland Ave. and an alley behind Nashville Rehabilitation Hospital;
- infiltration trench along the alley between Chicamauga Ave. and West Eastland Ave.;
- tree plantings along West Eastland Ave.; and
- a pervious concrete sidewalk along Bailey St.

Examples of these Green Infrastructure measures are shown in Figure 4.12.
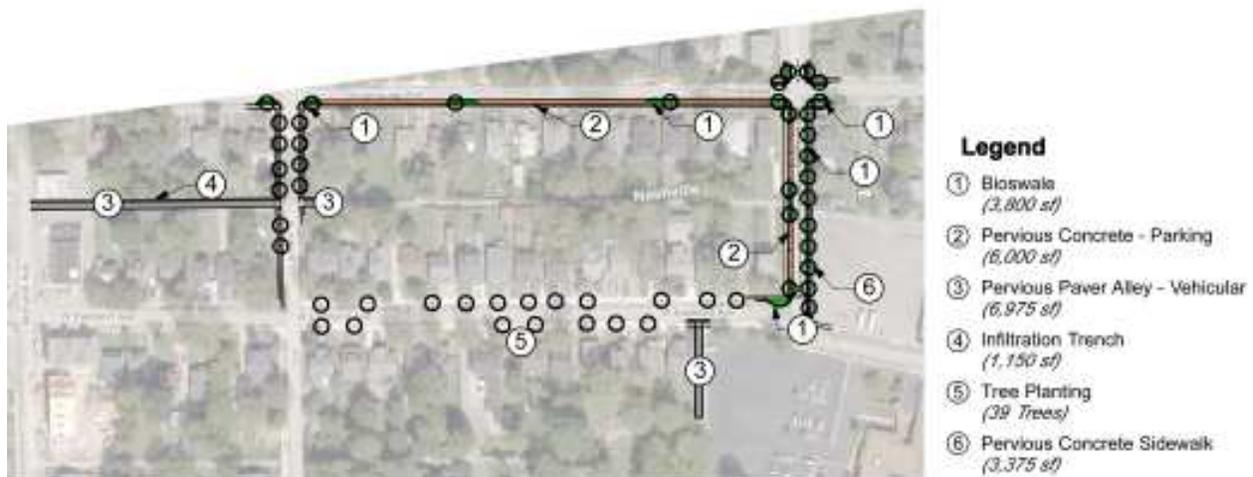
Figure 4.11—Project 1 Design Concept Plan.

Infiltration Trench   Pervious Paver Alley   Bioswale   Pervious Concrete

Figure 4.12—Examples of Green Infrastructure Measures Proposed for Project 1.

Ownership. The area of concern for flooding encompasses private residential parcels and public streets and alleys. The project as proposed will be located in the public right of way and associated drainage easements.

Maintenance Responsibility. This project uses linear systems located along public roadways and alleys. Therefore, long term maintenance for the project will be performed by Metro Public Works.

Estimated Stormwater Runoff Volume Reduction. This project is anticipated to reduce stormwater runoff volume from the project area by 3.8 million gallons annually.

Estimated Construction Cost. An opinion of probable cost (OPC) was generated based on the design concept plan. The OPC for Project 1 is approximately $933,000.

Supplemental Recommendations. The project will reduce runoff volume into the CSS as stated above. The project will also reduce the frequency and magnitude of flooding in the identified area of concern so long as other secondary factors are examined and mitigated. During the detailed design process, an examination should be made of the size and condition of the CSS lines in the project area and immediately downstream. It is possible that the ability of the CSS lines to convey stormwater runoff from the area of concern is limited.

4.3.2   Project 2 - Hume Fogg Academic Magnet High School

CSS Basin. 1st and Broadway basin.

Council District. District 19.

Location. Downtown Nashville at the intersection of Broadway and 7th Ave. N (Figure 4.13).

Figure 4.13—Project 2 Location Map.

Project Goal. The 1st and Broadway basin is the second smallest CSS basin with approximately 84 acres and it has the highest amount of impervious area (83%) of any of the CSS basins. The goal of the project is to intercept stormwater runoff from this site through the installation of a green roof and rainwater harvesting systems.

Proposed Green Infrastructure Measures. This site was selected as it is identified as a Metro Historic Landmark within the central business district of downtown. As such, its flat roof and historic significance is not unlike many other neighboring properties within this highly impervious CSS basin.

The conceptual design for this site is presented in Figure 4.14. The design includes:
- green roof covering a portion of the roof on the east side of the building that contains few, if any, roof penetrations;
- passive rainwater harvesting from a section of roof which is situated higher than the green roof; and
- rainwater harvesting from a section of roof that is situated lower than the green roof using a rainwater collection system comprised of two cisterns.

Examples of these Green Infrastructure measures are shown in Figure 4.16.

Figure 4.14—Project 2 Design Concept Plan.
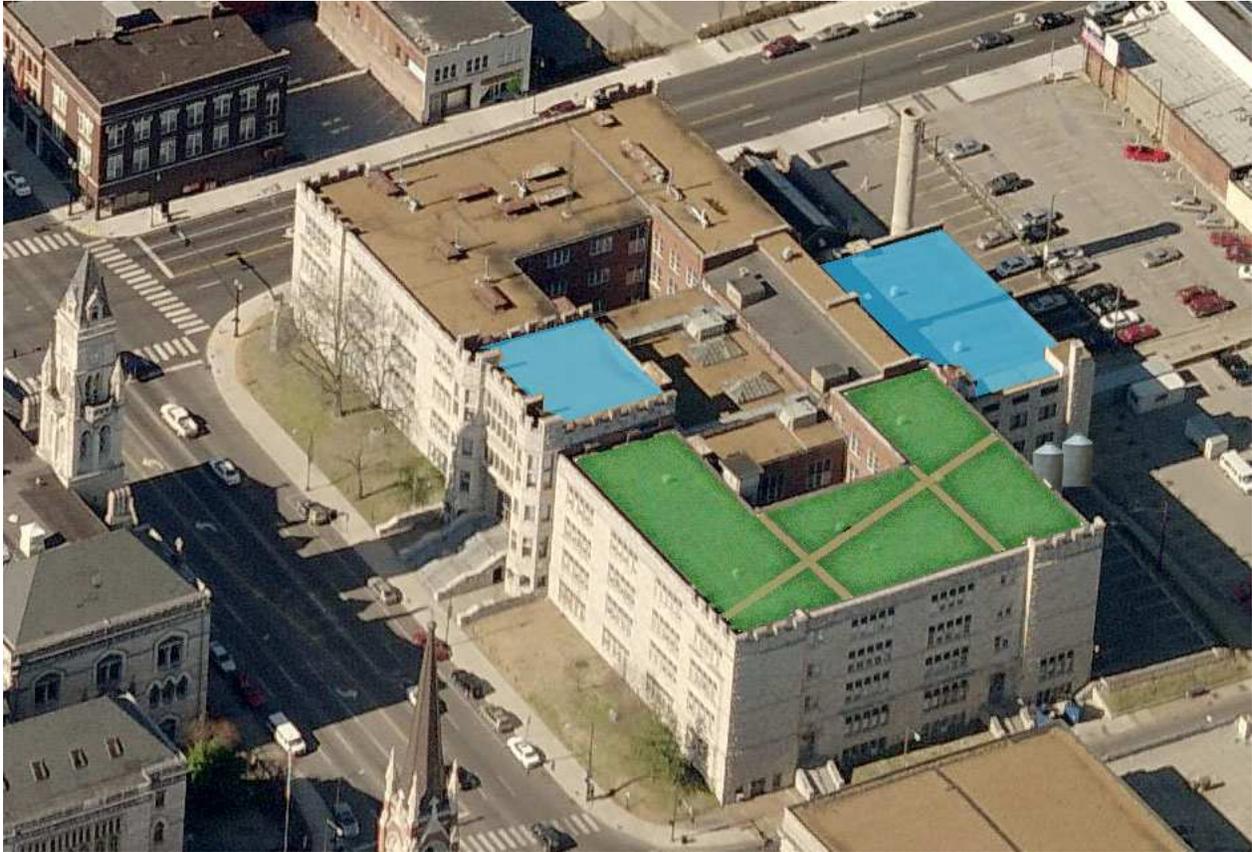
Figure 4.15—Birdseye Rendering for Project 2.

Extensive Green Roof   Water Harvesting   Extensive Green Roof   Extensive Green Roof

Figure 4.16--Examples of Green Infrastructure Measures Proposed for Project 2.

Ownership. The project site is owned by Metro Nashville Public Schools.(MNPS).

Maintenance Responsibility. Long term maintenance will be the responsibility of MNPS.

Estimated Stormwater Runoff Volume Reduction. This project is anticipated to reduce stormwater runoff volume from the site by 347,000 gallons annually.

Estimated Construction Cost. An opinion of probable cost (OPC) was generated based on the design concept plan. The OPC for Project 2 is approximately $410,000.

The cost estimate is based on the assumption that no structural enhancements to the building will be necessary in order to support a green roof. Further, the cost estimate does not include any repairs necessary to repair the existing roof.

Supplemental Recommendations. As an academic magnet, Hume Fogg has a demonstrated strong program in Advanced Placement (AP) Environmental Science, which may offer research opportunities and data collection for Nashville specific green roof research. To facilitate student research, access to the roof level will need to be provided as currently none exists.

A structural analysis should be performed during detailed design to verify that the structural condition of the building will support a green roof.

4.3.3   Project 3 – Farmer's Market

CSS Basin. Kerrigan basin.

Council District. District 19.

Location. In North Nashville east of Rosa L. Parks Blvd. between Jefferson St. and James Robertson Pkwy. (Figure 4.17)

Project Goal. The Kerrigan basin is the largest CSS basin with a drainage area of approximately 3,390 acres. The goal of the project is to intercept stormwater runoff from this site through the installation of a variety of Green Infrastructure measures in order lessen the stormwater runoff that flows into the CSS.
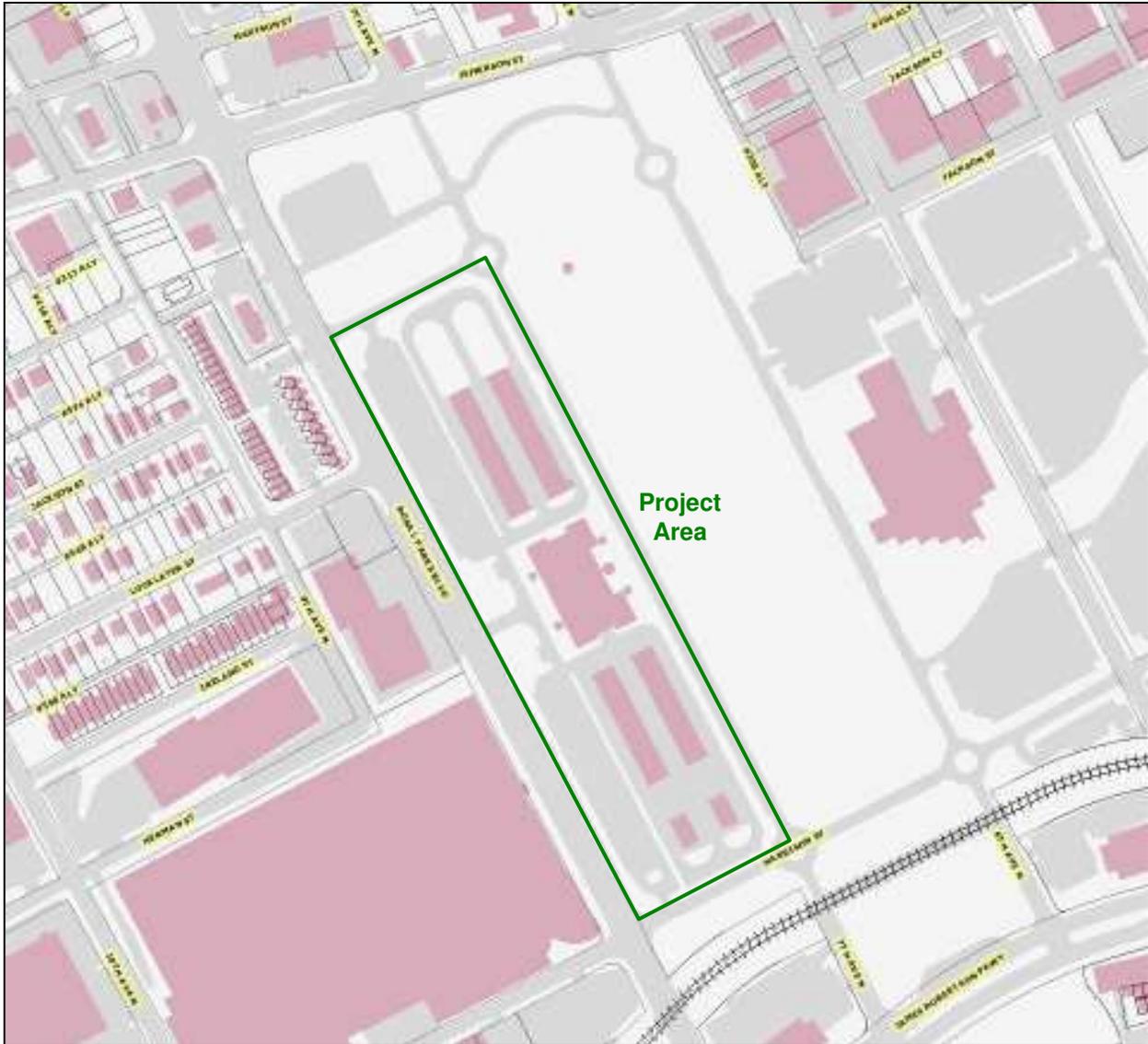
Figure 4.17—Project 3 Location Map.

Proposed Green Infrastructure Measures. This site was selected due to its location in North Nashville immediately adjacent to the State Bicentennial Mall and its daily attraction of the community to its facility.

The conceptual design for this site is presented in Figure 4.18. The design includes:
- Rainwater harvesting to collect runoff from the roofs of the sheds at the north and south ends of the project area. This rainwater harvesting would be used for irrigation for the garden and nursery vendors and the needs for wash off areas at vendor set up sites.
- Rainwater harvesting from the main shed in the middle of the property for use as water for urinals and toilets (grey water).
- Pervious pavers for the vehicular traffic areas between the sheds.
- Linear strips of pervious concrete along the edge of the parking lot adjacent to Rosa L. Parks Blvd. (8th Ave N).

Examples of these Green Infrastructure measures are shown in Figure 4.19.

Figure 4.18—Project 3 Design Concept Plan.

Pervious Concrete Pavers   Water Harvesting   Pervious Concrete

Figure 4.19--Examples of Green Infrastructure Measures Proposed for Project 3.

Ownership. The project site is owned by the State of Tennessee.

Maintenance Responsibility. Long term maintenance will be the responsibility of the Farmers Market.

Estimated Stormwater Runoff Volume Reduction. This project is anticipated to reduce stormwater runoff volume from the site by 4.0 million gallons annually.

Estimated Construction Cost. An opinion of probable cost (OPC) was generated based on the design concept plan. The OPC for Project 3 is approximately $1,200,000.

Supplemental Recommendations. The use of rainwater for flushing in the main building is currently against codes. An application for a variance will be needed to use rainwater for this purpose.

4.3.4   Project 4 – Parthenon Towers

CSS Basin. Kerrigan basin.

Council District. District 21.

Location. Along the western boundary of Centennial Park in West Nashville (Figure 4.20).

Figure 4.20—Project 4 Location Map.

Project Goal. The Kerrigan basin is the largest CSS basin with a drainage area of approximately 3,390 acres. The goal of the project is to intercept stormwater runoff from this site through the installation of Green Infrastructure measures in order lessen the stormwater runoff that flows into the CSS. The Centennial Park area is also subject to flooding during heavy rainfalls due to a lack of capacity in the combined sewer system lines in the area.

Proposed Green Infrastructure Measures. This project site is a senior affordable housing facility and community center immediately adjacent to Centennial Park. The community center meeting rooms are one-story facilities that have roofs overlooked by the residents of the contiguous high-rise residential tower. Parking areas are oversized based on standard parking bays widths. This presents a demonstration project for incorporation of green roof and

infiltration measures for an affordable residential facility.

The conceptual design for this site is presented in Figure 4.21. The design includes:
- 💧 Extensive green roof tray systems covering three of the low roofs on the site. A green roof is not proposed for the two towers.
- 💧 Bioswales in select areas within and around the parking lots.
- 💧 Linear strips of pervious concrete along low-lying areas of the parking lots.

Examples of these Green Infrastructure measures are shown in Figure 4.23.

Figure 4.21—Project 4 Design Concept Plan.

Figure 4.22—Project 4 Birdseye Rendering.

Extensive Green Roof　　　Pervious Concrete　　　Bioswale

Figure 4.23--Examples of Green Infrastructure Measures Proposed for Project 4.

Ownership. The project site is owned by the Metro Development and Housing Agency (MDHA).

Maintenance Responsibility. Long term maintenance will be the responsibility of MDHA.

Estimated Stormwater Runoff Volume Reduction. This project is anticipated to reduce stormwater runoff volume from the site by 1.3 million gallons annually.

Estimated Construction Cost. An opinion of probable cost (OPC) was generated based on the design concept plan. The OPC for Project 4 is approximately $620,000.

4.3.5   Project 5 – Metro Parks Administrative Facility

CSS Basin. Kerrigan basin.

Council District. District 21.

Location. West of Centennial Park at the intersection of Oman St. and Park Plz. (Figure 4.24).

Project Goal. The Kerrigan basin is the largest CSS basin with a drainage area of approximately 3,390 acres. The goal of the project is to intercept stormwater runoff from this site through the installation of Green Infrastructure measures in order lessen the stormwater runoff that flows into the CSS. Runoff from this site flows downstream to Centennial Park. The Centennial Park area is also subject to flooding during heavy rainfalls due to a lack of capacity in the combined sewer system lines in the area.

Proposed Green Infrastructure Measures. This site was selected due to its location within the city's prominent Centennial Park and its location as Metro Parks office and the site of Park and Recreation and Greenway board meetings and other public meetings. Through its constant interaction with citizens, the Parks department offers a strong education component as a demonstration site for a variety of best management practices using its large roof area for water collection and reducing its vast existing impervious surface areas.
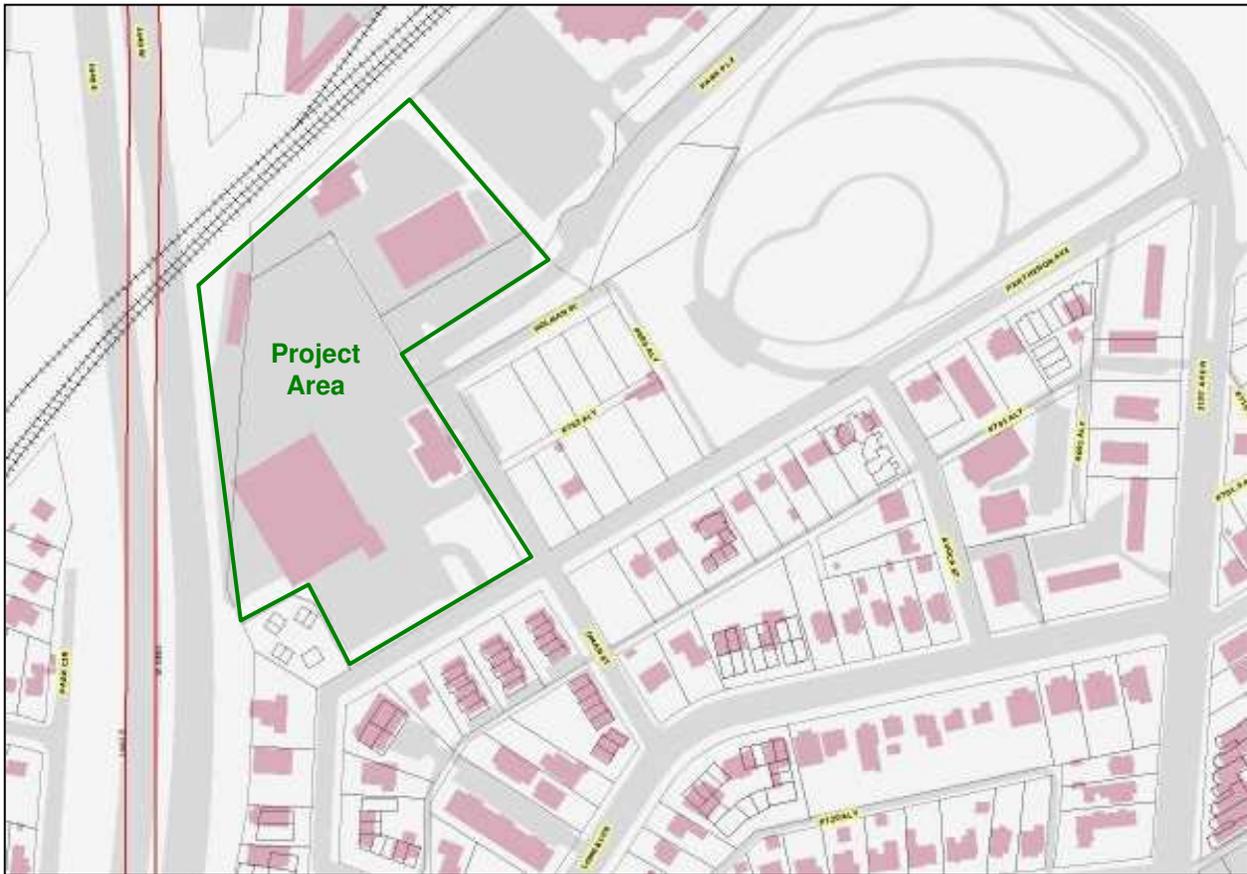
Figure 4.24—Project 5 Location Map.

The conceptual design for this site is presented in Figure 4.25. The design includes:

- Rainwater harvesting of runoff from portions of the roofs of three buildings. Some rainwater harvesting will be used for irrigation and some will be used as an alternative to potable water for operations and maintenance.
- Extensive green roof tray system covering a portion of the Administration Building.
- Bioswales in several locations within and around parking lots and buildings.
- Linear strips of pervious concrete in the parking lot along Park Plaza.
- Pervious pavers in pedestrian walkways in front of the Administration Building.
- Replacement of impervious pavement with open-graded pervious pavement in three areas inside the complex.

Examples of these Green Infrastructure measures are shown in Figure 4.27.

Figure 4.25—Project 5 Design Concept Plan.

Legend

1. Water Harvesting
   2 - 15' diam. Tanks - 36,200 gal Total Capacity
   2 - 12' diam. Tanks - 17,200 gal Total Capacity
   1 - 6' diam. Tank - 1,400 gal Capacity
2. Extensive Greenroof Tray System
   (4" depth - 1,550 sf)
3. Bioswale/Rain Garden
   (16,500 sf)
4. Pervious Concrete - Parking
   (6,200 sf)
5. Pervious Pavers - Pedestrian
   (1,500 sf)
6. River Rock Bed
   (1,200 sf)
7. Open Graded Aggregate Pavement
   (20,800 sf - Impervious pavement removal)

Figure 4.26—Project 5 Birdseye Rendering.

Extensive Green Roof   Pervious Concrete Pavers   Bioswale   Pervious Concrete

Figure 4.27--Examples of Green Infrastructure Measures Proposed for Project 5.

Ownership. The project site is owned by Metro Parks.

Maintenance Responsibility. Long term maintenance will be the responsibility of Metro Parks.

Estimated Stormwater Runoff Volume Reduction. This project is anticipated to reduce stormwater runoff volume from the site by 6.1 million gallons annually.

Estimated Construction Cost. An opinion of probable cost (OPC) was generated based on the design concept plan. The OPC for Project 5 is approximately $1,200,000.

4.3.6   Project 6 – Metro Public Works Facility

CSS Basin. Benedict and Crutcher basin.

Council District. District 6.

Location. Two blocks south of Shelby Ave. on South 5th St. (Figure 4.28).

Project Goal. The Benedict and Crutcher basin is a small basin containing approximately 277 acres. This basin is identified as one where problems with the CSS are likely to occur during moderate rainfall events. The goal of the project is to intercept stormwater runoff from this site through the installation of Green Infrastructure measures in order to lessen the stormwater runoff that flows into the CSS.

Proposed Green Infrastructure Measures. This site was selected as this location is currently used as a primary vehicle wash down location and for filling of Metro water trucks for maintenance purposes. The wash down site is immediately adjacent to a large roof structure available for water collection. This portion of the site also drains directly to the Cumberland River.

The conceptual design for this site is presented in Figure 4.29. The design includes:
- Rainwater harvesting of runoff from portions of the roofs of two buildings to be used as an alternative to potable water for operations and maintenance.
- An infiltration trench along a low-lying area of the parking lot to intercept surface flow off the parking lot.

Examples of these Green Infrastructure measures are shown in Figure 4.30

Ownership. The project site is owned by Metro Public Works (MPW).

Maintenance Responsibility. Long term maintenance will be the responsibility of MPW.

Estimated Stormwater Runoff Volume Reduction. This project is anticipated to reduce stormwater runoff from the site by 340,000 gallons annually.

Estimated Construction Cost. An opinion of probable cost (OPC) was generated based on the design concept plan. The OPC for Project 6 is approximately $88,000.

Figure 4.28—Project 6 Location Map.

Figure 4.29—Project 6 Design Concept Plan.

Infiltration Trench   *Water Harvesting*   *Infiltration Trench*

Figure 4.30--Examples of Green Infrastructure Measures Proposed for Project 6.

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5. Green Infrastructure Incentives and Financing

5.1 Promoting Green Infrastructure

More and more municipalities across the country are incorporating "green" techniques into their stormwater management strategies. To help advance Green Infrastructure and reduce the burden on stormwater management systems, these local municipalities are leading by example. For instance, here in Nashville a newly transformed Dedrick Street was unveiled as the first green street in Tennessee. Likewise, the City of Chicago's Green Alley Program created permeable alleys to allow the infiltration of rainwater into the soil, not the sewer system.

Experience elsewhere has indicated that the institutional aspects of Green Infrastructure are as important as the physical designs and construction. To most effectively grow and enhance the program there will need to be participation by both public and private landowners in Green Infrastructure practices. Often, especially in the initial phases of the program or if Green Infrastructure practices have a higher initial cost than current practices private parties can be encouraged to move ahead using incentives of various types. For example, Chicago saw a rapid increase in the use of green roofs when it began a financial incentive program. Cities across the country are developing Green Infrastructure incentives to encourage private landowners to incorporate "green" techniques as part of retrofitting of existing development or reducing runoff of future developments.

This section summarizes a suite of incentives that may be applicable for use in Nashville as the Green Infrastructure program begins to grow.

5.2 Incentive Approaches

A number of incentives were examined to encourage the use of Green Infrastructure for retrofitting existing developments and incorporating "green" stormwater practices in future developments. From these incentives five (5) were selected for further consideration for implementation in Metro Nashville:

- Stormwater Fee Discounts
- Rebates and Installation Financing
- Development Incentives
- Grants
- Awards & Recognition Programs

Following are brief descriptions of these five incentives including references to municipalities that have successfully implemented these incentives. The incentive descriptions are based primarily on information from *EPA's Municipal Handbook – Managing Wet Weather with Green Infrastructure – Incentive Mechanisms* (USEPA, 2009), supplemented with personal conversations and additional research.

Potential Incentives for Retrofitting Green Infrastructure:

- ✓ Stormwater Fee Discounts
- ✓ Tax Credits
- ✓ Subsidy Programs
- ✓ Grants
- ✓ Free Consultation and Workshops
- ✓ Awards and Recognition Programs

Potential Incentives for New Development:

- ✓ Expedited Permitting Process
- ✓ Fee Waivers
- ✓ Reduction in Stormwater Requirements
- ✓ Zoning Upgrades
- ✓ Increase Floor Area Ratio
- ✓ Awards and Recognition Programs

5.2.1 Stormwater Fee Discounts

Stormwater fees are normally based on some measure of the amount of impervious area on a site. This is because impervious surfaces are the primary cause of increased rainfall runoff, flooding and pollution. Green Infrastructure reduces these impacts and thus, qualifies for a credit under the stormwater user fee program. This incentive program encourages retrofitting of existing developments and the incorporation of Green Infrastructure practices in new developments. Listed below are three examples of stormwater fee discount programs.

Southeast Metro Stormwater Authority
Centennial, Colorado (Denver Area)
Stormwater Fee Equitability Program
Stormwater fees for all improved land are based on the ratio of Impervious Area (IA), which is the "footprint" of all surfaces on a parcel from which water would run off (i.e. roof, walkway, driveway, patio, parking lot, etc.). The annual stormwater fee charged to a property owner is based on the impact the property will have on the storm drainage system. The fee is billed on the Arapahoe County Tax Statement that is sent in January. Payment is due similar to the payment schedule of property tax payments. The IA is determined by aerial photography, which is taken annually and used with County records and Geographical Information System (GIS). From the information gathered for each parcel, the IA is identified and measured. The IA measurement is then used according to the fee rates, thus the higher the ratio, the higher the rate.

Reference(s): Southeast Metro Stormwater Authority
http://www.semswa.org/fees.htm#surface
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Metropolitan Sewer District
Louisville/Jefferson County, Kentucky
Drainage Charge Credit
Commercial property owners utilizing on-site retention or detention facilities are eligible for drainage charge credit adjustments for controlling peak flows. The credit incentive is dependent on how the retention or detention basin functions. There are a set of criteria that must be met and approved by the Metropolitan Sewer District (MSD). For instance, the basins must meet size requirements for 2-, 10-, or 100-year storms as well as limit discharges to pre-development runoff rates. Credits are available for each type of storm, with an 82% maximum credit if all criteria are met. The property owner is responsible for all costs of operation and maintenance of the facility.

Reference(s): Louisville and Jefferson County – Metropolitan Sewer District
http://www.msdlouky.org/pdfs/msdrates09.pdf
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Portland Bureau of Environmental Services
Portland, Oregon
Clean River Rewards Incentive and Discount Program
Property owners who manage stormwater on site and/or on the public right of way that serves their property are eligible for discounts at 35% of the stormwater charge for on site and 65% of the stormwater charge for public right of way. For residential properties, the discount is based on managing stormwater runoff from the roof areas only. The discount for commercial properties is based on managing stormwater runoff from both roof and paved areas. To maintain the discount, the utility account must remain active, stormwater facilities must be properly maintained and operated, and the city must be granted access to the property for limited inspections of stormwater facilities. Partial credits are available on a sliding scale for properties that manage any portion of stormwater on site, including partial credits for tree coverage and a credit for residential properties that have less than 1,000 square feet of total impervious area.

Reference(s): Portland Bureau of Environmental Services
    http://portlandonlime.com/BES/index.cfm?c=41976
    U.S. Environmental Protection Agency
    http://www.epa.gov/greeninfrastructure

5.2.2   Rebates and Installation Financing

Rebates and installation financing is made available to provide incentives for property owners to implement Green Infrastructure practices on their property. The incentive is typically provided in a special target area and can be in the form of grants, rebates or at discounted costs. Below are four examples of rebate and installation programs.

Stormwater Partners Network
Montgomery County, Maryland
RainScapes Rewards
Residential, commercial and private institutional property owners are granted financial rewards for the installation of rain gardens, rain barrels, green roofs, native plants, tree canopies and permeable pavers. The reward is $1,200 per single-family lot and up to $5,000 per multi-family or commercial property. The RainScapes Rewards program began in January 2008 and rebates will be processed until funds are depleted.

Reference(s): Stormwater Partners Network
    http://www.stormwaterpartners.org
    U.S. Environmental Protection Agency
    http://www.epa.gov/greeninfrastructure

City of Maplewood
Maplewood, Minnesota
Street Redesign and Reconstruction
Residential property owners participate in a large-scale redesign of existing streets and utilities, of which the City offer to construct standard-size rain gardens in the public boulevard right-of-way on the front edge of residential properties. These gardens handle drainage from yards, rooftops, driveways and some runoff from the street. Residents volunteer to have the garden built by the City and are responsible for planting the provided plants and maintaining the gardens with free technical assistance from the City.

Reference(s): City of Maplewood
http://www.ci.maplewood.mn.us/DocumentView.asp?DID=246
Resolve
http://www.resolv.org/rainscapesworkshop/Report.pdf
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

U.S. EPA Pilot Program
Cincinnati, Ohio
Mt. Airy Rain Catchers
A pilot project of EPA, Mt. Airy Rain Catchers was designed to test a reverse auction-based method to encourage the property owners in the Shepherd Creek watershed to participate in reducing stormwater runoff and pollution at the household level. Bids were received from qualified residents which outlined what rain catcher projects they agreed to have installed and the incentive payment they requested to do so. The bids were selected based on the project(s) they agreed to install, their scoring within an Environmental Benefit Index and the amount of incentive payment requested. The selected project(s) were installed for free and the residents were paid the bid amount as a one-time incentive payment. A total of 50 rain gardens and 100 rain barrels were installed in the first phase. In 2008, EPA decided to do another round of gardens and 31 additional rain gardens were installed and 60 additional rain barrels were installed. Homeowners were provided owner's manuals and Tetra Tech will maintain the rain catchers for three years.

Reference(s): Mt. Airy Rain Catchers
http://www.mtairyraincatchers.org/index.htm
U.S. Environmental Protection Agency
http://www.epa.gov/nrmrl/pubs/600r08129/600r08129.htm
http://www.epa.gov/greeninfrastructure

Portland Bureau of Environmental Services
Portland, Oregon
Downspout Disconnection Program
The program provides incentives to homeowners in targeted neighborhoods that are connected directly to the combined sewer system. There's a voluntary agreement between the homeowner and the City of Oregon to disconnect their downspouts and allow their roof water to drain to the gardens and lawns. The City's plumbing division works directly with the homeowner, which eliminates the need for a plumbing permit. The homeowner can arrange for the city to disconnect the downspout at no cost or do the work themselves and be reimbursed up to $53 per eligible downspout. The program is funded by a mixture of capital and operating funds due to pipe construction cost savings.

Reference(s): Portland Bureau of Environmental Services
http://www.portlandonline.com/bes/index.cfm?c=43081
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Green Roof Rebate Programs:

Portland Bureau of Environmental Services
Portland, Oregon
The ecoroof grant program is part of the City of Portland's Grey to Green effort to accelerate the City's work to increase Portland's green stormwater management infrastructure, protect sensitive natural areas and improve habitat. The city currently has about nine acres of ecoroofs scattered among more than 90 buildings. The Grey to Green goal is to add 43 acres of new ecoroofs in five years. The city will spend about $300,000 on grants in this fiscal year, and will make grant funds available over the next five years. The incentive grants will pay up to $5 per square foot for new ecoroof projects. Installation costs for ecoroofs in Portland can range from $5 to $20 per square foot. Industrial, residential, commercial and mixed-use projects are eligible for the incentive program.

Reference(s): Portland Bureau of Environmental Services
www.portlandonline.com/bes/ecoroof

Department of Environment
Chicago, IL
Since 2005, the Green Roof Grants Program helped realize more than 20 green roof projects throughout Chicago per year. Building on this success, the City of Chicago Department of Environment began giving an increased number of $5000 grants to assist with residential or small commercial green roof projects. "Small commercial" is a building with a footprint of less than 10,000 square feet. Sessions on the Program are held at the Chicago Center for Green Technology, 445 North Sacramento Avenue. Successful projects are announced in December. Grants assist in realizing new green roof projects throughout the City. Projects are selected in a 'blind' process and evaluation criteria included project location, visibility, project type as well as overall environmental benefit.

Reference(s): City of Chicago Department of Environment
http://egov.cityofchicago.org/city/webportal

NYC Department of Buildings
New York City, New York
Building owners in New York City who install green rooftops will now receive a significant tax credit .Under this law, building owners in New York City who install green roofs on at least 50 percent of available rooftop space can apply for a one-year property tax credit of up to $100,000. The credit would be equal to $4.50 per square-foot of roof area that is planted with vegetation, or approximately 25 percent of the typical costs associated with the materials, labor, installation and design of the green roof.

Reference(s): NYC Department of Buildings
http://www.nyc.gov/html/dob/html/sustainability/green_roof_faq.shtml

Lice Green Toronto
Toronto, Ontario, Canada
A new Eco-Roof incentive program was launched at the end of February 2009 on the LiveGreen Toronto website. Toronto's Eco-Roof Incentive Program is designed to promote the use of green and cool roofs on Toronto's commercial, industrial and

institutional buildings, and help Toronto's business community take action on climate change. The City announced the first round of successful applicants for its Eco-Roof Incentive Program – Spring 2009. In total, 22 applicants were awarded a cumulative $500,000. The program provides incentives of $50 / square metre of green roof up to $100,000 per award and $2-$5. Initial funding for Eco-Roofs was approved in 2007, totaling $2.4 million over 5 years. Additional funding of $200,000 per year is provided by Toronto Water to be specifically allocated to green roof projects.

Reference(s): Live Green Toronto
http://www.toronto.ca/livegreen/bus_eco-roof.html

5.2.3   Development Incentives

Development incentives were created for private developers. The incentive could waive or reduce fees, requirements, zoning standards, or steps in the permitting process. To qualify for the incentives, the developer must incorporate sustainable site design and green building practices in accordance to the existing development regulations. Below are development incentives currently being offered to developers in four cities.

Department of Construction and Permits
Chicago, Illinois
Green Permit Program
Architects, developers and building owners can be part of an expedited permit process by adding elements of green building strategies and technologies from a menu of items created by Chicago's Department of Construction and Permits. This program will save developers time and money. Projects approved for the Green Permit Program can receive permits in less than 30 business days instead of the 60 to 90 days normally required to secure permits. Projects that display a high level of green strategy can possible result in the fees waived for consultant code review. A team of green building experts are available to assist applicants with navigating the permitting process to ensure timely implementation of these technologies.

Reference(s): City of Chicago Department of Construction and Permits
Index Publishing Corporation
http://www.chicagocodes.com/display_news.cfm?news_id=252
Chicago Center for Green Technology
http://cityofchicago.org
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

City of Philadelphia
Philadelphia, Pennsylvania
Green Roofs Tax Credit
Commercial building owners may receive a credit for a green roof covering at least 50% of the building's rooftop or 75% of eligible roof top space. In addition, the applicant may claim a tax credit for 25% of all costs associated with the construction of the green roof, provided that the total tax credits for a green roof do not exceed $100,000. The tax credit is applied against the applicant's total business privilege tax liability for the tax year when verification of green roof completion is submitted and approved.

Reference(s)   City of Philadelphia
                      http://webapps.phila.gov/council/attachments/3533.pdf
                      U.S. Environmental Protection Agency
                      http://www.epa.gov/greeninfrastructure

Bureau of Planning and Sustainability
Portland, Oregon
Floor Area Ratio Bonus
Commercial buildings in the Central City are eligible for FAR bonus based on three
ranges of ecoroof coverage in relation to the footprint of the building. Buildings with
ecoroof coverage of 10-30%, 30-60% and 60% or greater earn one, two and three
square feet of additional floor area per square foot of ecoroof respectively.

Reference(s): City of Portland – Bureau of Planning and Sustainability
                      http://www.portlandonline.com/osd/index.cfm?a=114728&c=42113
                      U.S. Environmental Protection Agency
                      http://www.epa.gov/greeninfrastructure

Stormwater Management
Knox County, Tennessee
Impervious Area Disconnection
Developers may be granted a credit when impervious areas are disconnected from the
stormwater control system via overland flow filtration/infiltration (i.e. pervious) zones.
The pervious areas are incorporated into the site design to receive runoff from rooftops
or other small impervious areas. This can be achieved by grading the site to promote
overland vegetative filtering or by providing infiltration or "rain garden" areas. If
impervious areas are adequately disconnected in accordance with the criteria, they can
be deducted from the total site area when computing the water quality volume
requirements.

Reference(s): Knox County Stormwater Management
                      http://www.knoxcounty.org/stormwater
                      U.S. Environmental Protection Agency
                      http://www.epa.gov/greeninfrastructure

5.2.4   Grants
Grants present an effective way to provide financial assistance directly to individuals, property
owners, community groups, nonprofit organizations and targeted geographical areas. In many
cases, grant funds are used to implement pilot projects, which introduce Green Infrastructure
practices at no cost to the user. Listed below are examples of four grant programs.

Office of Sustainability and the Environment
Santa Monica, California
Sustainable Landscape Program
Grants are awarded for up to 50% of the cost of the project, not to exceed $5,000,
including a maximum of $3,500 for qualified irrigation equipment and a maximum of
$1,500 for climate-appropriate plants. No turf or high water using plants or invasive
plants will be funded. The project must conform to the City's Green Building Ordinance
(GBO). The required irrigation and planting plans must be approved prior to purchase of
products/plants and installation of the products/plants in order to receive funding.

Irrigation equipment and/or plants that have already been installed are not eligible for grant funding.

Reference(s): Santa Monica – Office of Sustainability and Environment
http://www.smgov.net/epd/residents/Water/Landscape_Grant.htm
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Department of Community Development
Chicago, Illinois
Green Roof Improvement Fund
The Green Roof Improvement Fund (GRIF) is a pilot program to provide financial assistance for the installation of green roofs on eligible commercial facilities within the Central Loop Tax Increment Financing (TIF) district. GRIF assistance is available for certain costs associated with the installation of a green roof. The system covers at least 50% of the main roof of a building and is designed to be low-maintenance. Eligible costs for installation include but are not limited to engineering, design and construction. Any current or prospective commercial building owner located in the Central Loop TIF district may apply for GRIF funding. All grants shall be in the form of reimbursement funding to be awarded after the green roof is installed. In addition, all owner applicants must demonstrate that they have a minimum two-year maintenance agreement for the green roof.

Reference(s): City of Chicago- Department of Community Development
http://egov.cityofchicago.org/city/webportal/portal
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Portland Bureau of Environmental Services
Portland, Oregon
Community Watershed Stewardship Grants

Environmental Services collaborates with Portland State University, Americorps, local watershed councils and the community to raise awareness of and to improve watershed health. The Watershed Stewardship grants provide up to $10,000 to schools, churches, businesses and other community organizations for projects that protect and enhance watershed health at the local level. Groups can use grant money for supplies, materials, equipment, room rentals, feasibility studies or technical assistance. Past projects include education and monitoring, ecoroofs, stormwater features, restoration, and naturescaping.

Reference(s)   Portland Bureau of Environmental Services
http://www.portlandonline.com/BES/index.cfm?c=43077
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Natural Resources and Parks
King County, Washington
Impervious Surface Cost Share and Credit Program
This incentive is available to commercial property owners to reduce impervious surfaces. The County makes funds available for sharing the costs associated with converting impervious surface to native vegetated landscape, compost-amended lawn or grass, modular-grid pavement. To qualify, a plot plan, technical information and description must be submitted. The county engineer will work with the applicant to develop the plan. After the project is completed and inspected, 50% of costs up to $20K will be reimbursed. Reducing impervious surface could potentially place property into a lower rate category, reducing the stormwater fee.

Reference(s): King County – Natural Resources and Parks
http://www.kingcounty.gov/environment
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

5.2.5   Awards and Recognition Programs

Awards and recognition programs serve as an excellent marketing tool for Green Infrastructure. It presents a unique opportunity for municipalities and businesses to showcase best management practices, increase public awareness of local projects and celebrate the accomplishments of the award recipients.

Mayor Daley's GreenWorks Award – Chicago, IL
This annual award promotes a green city by recognizing businesses, nonprofit, schools and government agencies whose buildings, practices/services or products are environmentally responsible. There are three awards categories: green buildings, green practices, and green products. Special consideration is given to projects with an educational and outreach component.

Reference(s): City of Chicago- Department of Environment
http://egov.cityofchicago.org/city/webportal/portal
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Businesses for an Environmentally Sustainable Tomorrow (BEST) – Portland, OR
Since 1993, the BEST Awards have been presented annually to Portland area companies demonstrating excellence in business practices that promote economic growth and environmental benefits. The BEST Awards recognizes businesses with significant and unique achievements in the following categories: BEST Practices for Sustainability for Small, Medium and Large companies; Sustainable Products and Services; Innovation in Resource Conservation, Green Building and Sustainable Food Systems.

Reference(s): Portland Bureau of Environmental Services
http://www.portlandonline.com/OSD/index.cfm?c=41891
U.S. Environmental Protection Agency
http://www.epa.gov/greeninfrastructure

Eco-logical Business Program – Portland, OR
A certificate and recognition program to highlight environmentally friendly businesses. After certification visit, participating shops receive a shop display package, press coverage, listing on the program web site and promotion on the radio and at public events.

Reference(s): Portland Pollution Prevention Outreach
  http://www.ecobiz.org/
  U.S. Environmental Protection Agency
  http://www.epa.gov/greeninfrastructure

Philadelphia Sustainability Awards - Philadelphia, PA
Projects from businesses, nonprofits, community organizations, individuals, schools and government agencies in the Greater Philadelphia region are granted recognition awards for sustainability in a variety of categories, including water efficiency/conservation, pollution prevention, landscaping/greening, habitat protections, best management practices, stormwater management and green building elements.

Reference(s): Philadelphia Sustainability Awards
  http://www.philadelphiasustainabilityawards.org/
  U.S. Environmental Protection Agency
  http://www.epa.gov/greeninfrastructure

Stormwater BMP Recognition Program – Philadelphia, PA
This program recognizes innovative stormwater best management practices (BMP) in the southeastern region of Pennsylvania. The program is looking for projects such as rain gardens, green roofs, infiltration swales and treatment wetlands. Those who are recognized will receive a certificate and/or award from top officials of the Department of Environmental Protection and the City of Philadelphia, recognition at an awards ceremony, and region-wide media exposure.

Reference(s): Temple-Villanova Sustainable Stormwater Initiative
  http://www.stormwaterbmp.org/stormwaterbmp/
  U.S. Environmental Protection Agency
  http://www.epa.gov/greeninfrastructure

Businesses for Clean Water – King County, WA
The Businesses for Clean Water program recognizes companies that successfully prevent stormwater pollution at their sites.

Reference(s): Stormwater Solutions
  http://www.envirostars.com/news/articles/detail.cfm
  U.S. Environmental Protection Agency
  http://www.epa.gov/greeninfrastructure

5.3   Funding Approaches

Local municipalities across the country are exploring ways to generate reliable funding sources to implement Green Infrastructure practices to help manage stormwater runoff. Data collected on the impact of "green" stormwater management techniques has proven that Green Infrastructure is an effective strategy at a cost that can be less than or equal to the cost of traditional stormwater management systems. Green infrastructure practices are creating cities that are environmentally-friendly, fiscally-responsible and sustainable for future generations.

However, the immediate challenge for local municipalities interested in expanding the integration of Green Infrastructure with the traditional systems is securing revenue. There are generally considered to be three categories of sources to fund Green Infrastructure: stormwater fees, loan programs and grants. Of the three sources, a stormwater user fee is the most reliable. There may also be ancillary fees or surcharges or special rate approaches within the rate structure that can bring about enhancement of the Green Infrastructure program.

Grants are very limited in availability and funding amounts. Unlike stormwater fees and loans, grant funding for Green Infrastructure is not appropriate to fund large investments. It is only sufficient to fund small, local projects, such as neighborhood demonstration projects. As such, municipalities are exploring funding sources at every level of government, loans programs, and foundations/nonprofit organizations.

Below are some specific grant-based funding options pertinent to Nashville that have been used to support Green Infrastructure as well as some potential future sources of revenue.

5.3.1   Federal Funding Options

- The American Reinvestment and Recovery Act of 2009(ARRA) totaling $787 billion was enacted in February 2009. It dedicated 20% of the domestic spending in water infrastructure must be allotted to Green Infrastructure. Funds are administered by Tennessee Department of Environment and Conservation (TDEC).

- Green Retrofit Program for Multifamily Housing (U.S. Housing and Urban Development) provided $250M in loans and grants for energy and green retrofits in the multi-family assisted housing stock. The goal is to created green collar jobs; improve property operations by reducing utility expenses; benefit resident health and the environment.

- The Urban Revitalization and Livable Communities Act, HR 3734 is a new legislation being proposed by Rep. Albio Sires of New Jersey and 22 co-sponsors. The request is to authorize $445 million to be appropriated annually for FY2011-2021. Funding would be provided through matching federal assistance grants and could be used by parks and recreation agencies to rehabilitate and develop new urban parks and community recreational infrastructure, encourage environmental stewardship and foster local economic development.

5.3.2   State Funding Options

- State Revolving Loan Fund provides assistance through a series of grants and loans to support local communities with the development and maintenance of drinking water and waste water infrastructure. These very low interest loans support water and wastewater

system projects so communities can achieve and maintain compliance with regulatory standards and improve water quality.

⬥ Clean Water State Revolving Fund (CWSRF) Loan Program – This loan fund program is administered by the State Revolving Loan Fund. An amendment to the Federal Clean Water Act in 1987 created the CWSRF Program in order to provide low-interest loans to cities, counties, and utility districts for the planning, design, and construction of wastewater facilities. The U.S. Environmental Protection Agency awards annual capitalization grants to fund the program, and the State of Tennessee provides a twenty-percent funding match.

⬥ Tennessee Department of Environmental Conservation (TDEC) Green Development Grant – Created in 2008, this is the first Green Infrastructure and low impact development grant program to fund projects implementing Green Infrastructure and low impact development practices throughout the State of Tennessee. Four grants totaling $100,000 were awarded to the City of Athens ($30,000); the City of Knoxville ($10,000); the City of Lakeland ($30,000) and the Metro Nashville ($30,000). The recipients must complete the projects within two years of receiving the award. Currently, there are no resources to implement the second round of grants.

5.3.3   Local Funding Options

⬥ Clean Water Infrastructure Program – is a stormwater fee program instituted by Metro to raise revenue for improvements/upgrades to Metro's stormwater management systems.

⬥ Nonprofit Organizations (indirect revenue) – The Land Trust for Tennessee, in partnership with the Metropolitan Planning Department and the Metropolitan Greenways Commission, is developing a Open Space Plan for Davidson County. The plan is being funding by a grant from the Martin Foundation.

⬥ The ULI Nashville Infrastructure Committee, working with Metro Water Services and Cumberland River Compact submitted a grant proposal (October 2009) to ULI Community Action Grant program to assist Metro in providing Supplemental Environmental Projects (SEP) to counter the current level of sewer overflow within the system. If awarded, the grant program would fund a rain garden initiative and stream buffer restoration/greenway/beautification.

⬥ Tax Increment Financing and Community Development Block Grant Funds (indirect revenue) administered by the Metropolitan Development and Housing Agency to promote the revitalization of low-income communities through economic and community development. Funding for infrastructure-related activities should utilize "green" techniques.

6 Recommendations for Next Steps

This section discusses a set of recommendations for the implementation of a green infrastructure program in Nashville.

6.1 Overview

Nashville has embarked on a wide ranging sustainability effort which has been spearheaded by the mayor's Green ribbon committee. Green Infrastructure fits into an overall sustainability effort as one piece. The GI master planning effort has begun the process of establishing a green infrastructure program and component of the stormwater management program. However a master plan is only one part of what is necessary to have a successful green infrastructure culture in Nashville.

6.2 Components of a Green Infrastructure Program

GI has both physically related program components and policy or institutional components. These components mimic stormwater programs generally – so there are no great surprises in what constitutes a comprehensive green infrastructure program within a city.

Often it is convenient to look at the life cycle of a project to determine where local support is not fully developed. Below are the key development and ongoing lifecycle components with an eye toward GI.

Planning – Does the structure and support documents exist for a developer to know they can use GI on their site and that the process will be smooth and sure? How do the concepts of GI need to be integrated into parks planning, street planning, etc.? What kind of incentives need to exist to make GI more attractive to planners? What kind of public and developer education is necessary to encourage the use of GI at the beginning for project conceptualization?

Development – Does the city have appropriate design criteria, trained reviewers, appropriate zoning, and design specifications that can accommodate GI in everything from parking lot and building to street design? For example, how would Nashville codes and processes need to be changed to accommodate graywater designs? Are policies in place to allow for a mixture of street and rooftop water to flow to a green street? What kind of testing and inspection needs to be done to insure that infiltration designs function as planned and do not damage surrounding infrastructure?

Construction –What kind of inspection is necessary as construction occurs? How will the multitude of GI practices be tracked as developments are approved? How will the inspection demands change when GI is a predominant component of a design?

Maintenance – Does the City have the necessary legal agreements to insure long-term maintenance of GI both on public and private property? What kinds of policies, technical support tools and staffing need to exist to help ensure enforcement of long term maintenance? How are public-private GI applications maintained?

6.3 Specific Steps

While the answers to these questions may be complex and interwoven, in our experience communities can begin slowly and build individual components into a larger overall program. For example, it is possible to begin to encourage Green roofs without having a comprehensive GI program in other aspects. Or it is possible for the City to begin to construct demonstration projects and to advertise their existence to begin to encourage private investment.

With that in mind here are some specific steps that we would recommend to be implemented in the next phase of GI program implementation:

Construct and Monitor Public GI Projects

     💧 Insure each project is constructed as designed and then insure adequate maintenance and monitoring takes place. The early designs may need adjustments that frequent inspection and monitoring will identify. This will create greater confidence as the program goes forward. Look for grant money and innovative programs to monitor sites. For example it may be valuable to have students from Hume Fogg provide significant monitoring of the Green Roof.

     💧 Advertise successful projects through the use of tours, information on the web, and signage. Let them be seen, understood and appreciated. Insure they are aesthetically pleasing.

> In an effort to promote sustainable development, Portland OR has implemented multiple green infrastructure projects and programs and become a leader in the green infrastructure movement. In addition, the city has developed a series of policy decisions, which include requiring new municipal buildings to a green roof and paying homeowners for disconnecting their downspouts.

Review and Change Departmental Policies and Regulations

     💧 Meet with different departments to identify and find ways to handle barriers to GI implementation. See how other communities have overcome them and mimic applicable successes.

     💧 Bring about changes to codes, policies, procedures, and laws that are barriers to GI.

     💧 Create a suite of incentives for appropriate GI use.

> In an effort to protect local water quality and improve quality of life for residents, Lenexa initiated the Rain to Recreation program. Since the program began in 2000, it has grown to include both regulatory and non-regulatory approaches. One program highlight has been creating riparian greenways through application of the stream setback ordinance, and requiring green infrastructure practices on site.

Change Design Criteria

     💧 Begin with draft criteria based on the best available information. As more experience is gained change criteria to match the realities on the ground.

     💧 Implement appropriate infiltration testing requirements for those practices that rely on infiltration for volume removal.

Begin Individual Practice Programs

     💧 Identify practices (such as green roofs, urban trees or cisterns) that can stand somewhat alone in terms of implementation. Begin to understand the success of other cities, craft and implement robust programs to encourage these kinds of practices.

     💧 Modify the current stormwater user fee rate structure to provide further incentives for more integrated practices.

> Chicago's green roof program began with the 20,300 square foot demonstration roof placed on Chicago City Hall. As a result of the success of the demonstration roof, Chicago launched an extensive green roof program, installing more than 80 green roofs in the city, as part of their green infrastructure initiative.

Educate

- Implement regular public and stakeholder education programs, field trips, design seminars.
- Create an informative GI website.
- Implement a stronger citizen program.

Partner with New Development

- Look for redevelopment and revitalization projects which may be good partners for GI implementation and partner with developers.

Look for Grant Opportunities

- Many of the leading programs around the United Sates have capitalized on their leadership position to obtain significant grant money both from public and private institutions. Such examples can be studied and followed.
- Strengthen relationships with key regulators who control, or recommend financial support for programs. For example, there is a Green Infrastructure management structure within USEPA that has access or can recommend targets of funding.
- Local companies will often agree to partner either in projects or in grant making to improve parks, streets or other areas – and the sustainable draw can be significant.

The City of Lansing implemented a rain garden project that extends over four city blocks of Michigan Avenue. The implementation of these rain gardens have helped ease peak flows for nearly 90% of storm events. Public Education efforts have led to the City of Lansing instituting an "Adopt-a-Garden" program and a partnership with a local science museum.

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Appendix 1

Ordinance BL2008-345

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SUBSTITUTE ORDINANCE NO. BL2008-345

An ordinance amending Title 15 of the Metropolitan Code to create a stormwater master planning district.

WHEREAS, approximately 14 square miles of central Davidson County is served by a Combined Sewer System (the "CSS") in which sanitary sewage and stormwater are conveyed in the same pipe; and

WHEREAS, during periods of wet weather, the amount of stormwater entering the CSS often exceeds the capacity of the system and leads to Combined Sewer System Overflows ("CSO"); and

WHEREAS, in 2007, 765.2 million gallons of CSO was discharged into the Cumberland River; and

WHEREAS, in August 2007, the Metropolitan Government signed a consent decree with the Department of Justice and the State of Tennessee that called for a 9 year plan to reduce raw sewage overflows in Davidson County's waterways; and

WHEREAS, the development of the area served by the CSS has resulted in more impervious surfaces and increased demands on the CSS; and

WHEREAS, the use of Green Infrastructure to encourage stormwater absorption and infiltration is an attractive and cost-effective way to reduce use of the CSS and enhance its function; and

WHEREAS, other parts of Davidson County not served by the CSS will also benefit from use of Green Infrastructure to reduce flooding and enhance water quality.

NOW, THEREFORE, BE IT ENACTED BY THE COUNCIL OF THE METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY:

Section 1. That Section 15.64.010 of the Metropolitan Code is hereby amended by adding the following new definitions to Section 15.64.010:

"Stormwater Master Planning District" means a defined geographical area that will benefit from the use of Green Infrastructure to augment or replace conventionally engineered stormwater management solutions.

"Green Infrastructure" means an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly, which incorporates management approaches and technologies that infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies. Green Infrastructure practices include, but are not limited to open space, rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, swales, and curb extensions.

"Green Street" means a public right-of-way that utilizes Green Infrastructure to manage wet weather flows and enhance water quality.

Section 2. That Title 15 of the Metropolitan Code, Water, Sewer and Other Public Places, is hereby amended by adding the following new Section 15.64.195 "Stormwater Master Planning District."

15.64.195 Stormwater master planning district.
A. There is hereby created a Stormwater Master Planning District within the geographical limits of the Metropolitan Government of Nashville and Davidson County and co-terminus with the area currently served by the Combined Sanitary Sewer System, as described by lines, words and figures on the maps on file with the Department of Water and Sewerage Services, which are incorporated herein by reference.
B. In cooperation with the Metropolitan Planning Department, the Metropolitan Development and Housing Agency, and the Department of Public Works, the Metropolitan Department of Water and Sewerage Services ("MWS") shall be responsible for developing a plan for the installation of Green Infrastructure within the Stormwater Master Planning District. At the discretion of the director of Metro Water Services,

the Stormwater Master Planning District may be subdivided into appropriate study areas.

C. Such plan for a Stormwater Master Planning District should include general location and type of installation and its estimated impact on the CSS.

D. The initial plan shall be submitted to the Metropolitan Council not later than one hundred eighty days from the effective date of this ordinance, and shall be updated annually as part of the report by the director of MWS pursuant to section 15.64.034 of this chapter.

E. Funding.

1. The director of MWS shall submit to the Mayor and the Director of Finance a list of Green Infrastructure projects within the Stormwater Master Planning District(s) for suggested inclusion as part of the capital improvements budget not later than four months prior to the end of the fiscal year, as provided in section 6.13 of the Metropolitan Charter.

2. Not less than thirty days after the adoption of the capital improvements budget each year, the director of MWS shall further submit to the Mayor and the Director of Finance a prioritized list of Green Infrastructure projects within the Stormwater Master Planning District(s) for recommended inclusion as part of the next capital spending plan. Such recommendation shall include estimated construction and maintenance costs as well as anticipated benefit to water quality and water treatment.

F. The Department of Water and Sewerage Services, working in conjunction with the Department of Public Works, shall be responsible for the maintenance of any publicly funded Green Infrastructure projects within the Stormwater Master Planning District(s). Such maintenance shall be done in accordance with specifications and standards established by MWS.

G. Notwithstanding the geographical limitations imposed by the Stormwater Master Planning District, the Department of Water and Sewerage Services shall have the authority to promulgate and enforce rules and regulations for the implementation of Green Infrastructure techniques to address stormwater issues associated with private development.

H. Subsequent to the enactment of this section, additional areas within the Metropolitan Government of Nashville and Davidson County may be designated as Stormwater Master Planning Districts by a resolution of the Metropolitan Council receiving twenty-one affirmative votes.

Section 3. That this Ordinance shall take effect from and after its passage, the welfare of The Metropolitan Government of Nashville and Davidson County requiring it.

Sponsored by: Parker Toler, Emily Evans, Mike Jameson, Jason Holleman, Erik Cole, Megan Barry, Randy Foster

LEGISLATIVE HISTORY	
Introduced:	November 18, 2008
Passed First Reading:	November 18, 2008
Referred to:	Budget & Finance Committee Public Works Committee
Deferred to January 20, 2009:	December 2, 2008
Substitute Introduced:	January 20, 2009
Passed Second Reading:	January 20, 2009
Passed Third Reading:	February 3, 2009
Approved:	February 10, 2009
By:	Karl F. Dean
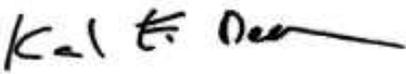
Appendix 2

Summary of Successful Green Infrastructure Programs
In Other Municipalities

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Four Successful Green Infrastructure Programs in the US

City Review

The purpose of this review is to provide Nashville with examples of successful Green Infrastructure programs to assist in the development of the Metro Nashville Green Infrastructure Master Plan.

Highlighted Cities:

✓ Philadelphia, PA
✓ Chicago, IL
✓ Portland, OR
✓ Seattle, WA

According to the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program study, two-thirds of urban streams have excessive nutrient pollution, and levels of fecal coliform bacteria that commonly exceed standards for water recreation. Water quality pollution impacts the beneficial uses of receiving waters (e.g. aquatic life, recreation) and represents a significant cost to cities striving to meet increasingly stringent state and federal water quality regulations.

Nashville is faced with increased population growth and continuous budget constraints. This increased urban development traditionally results in a greater percentage of impervious surfaces (e.g. streets, rooftops, driveways, and parking lots), causing an increase in stormwater runoff volume and flow rates. The increase in stormwater runoff can cause flooding and represents a threat to public safety and property. Nashville can establish itself as a leader in sustainability and meet the challenge of balancing growth and environmental protection by incorporating LID, or Green Infrastructure, into both new and redevelopment efforts.

Many cities throughout the United States, including the southeast region, are beginning to incorporate alternative stormwater management into their regulations. A few examples of Green Infrastructure efforts in the southeast are as follows:

- Alabama
  - Green Infrastructure Demonstration Project, Alabama Forestry Commission Urban and Community Forestry Financial Assistance Program: Beginning in 2008, this $60,000 federal cost share is aimed at providing green infrastructure education by showing a successfully implemented project.
  - The City of Auburn developed a City of Villages concept plan in 2003 to begin identifying ways of implementing Green Infrastructure. Several other cities throughout the Alabama are developing comprehensive Green Infrastructure planning programs. For more information visit Alabama Community Planning link listed below.
- Florida
  - The State of Florida made provisions to the State Building Code in 2007 requiring a minimum solar reflectance of 0.70 and minimum thermal emittance of 0.75. Florida also has a cool-roof credit program for residential buildings that started in 2001.
  - Additional states in the southeast with cool roof codes, standards, or programs include Arkansas, Georgia, Louisiana, North Carolina, and South Carolina.
- Georgia
  - Green Infrastructure workshops have been held over the past several years including a NPDES training/Green Infrastructure workshop by US Environmental

Protection Agency (EPA), the Georgia Master Gardener urban forestry training by Urban Forestry South, and a Green Infrastructure workshop by the Georgia Department of Natural Resources and University of Georgia Marine Extension Service

♦ North Carolina
   o In June 2009, the North Carolina Governor signed House Bill 239 to restore the water quality of the Jordan Watershed (in the Research Triangle area of NC) by implementing controls on nutrient loading from existing development.
   o In 2001 the University of North Carolina Chapel Hill began designing Green Infrastructure Best Management Practices (BMPs) for installation throughout the campus. The installation began the following year and the campus now has four porous pavement parking lots and above and below ground cisterns at an education center. Future plans include incorporation of cisterns in new building designs and the creation of a non-potable water utility.

♦ North Carolina/South Carolina/Georgia
   o The Chattooga Watershed Green Infrastructure Plan is a partnership developed to protect the 179,000 acre Chattooga watershed through Green Infrastructure implementation that preserves, restores, and maintains the native forest ecosystem.

♦ Southeastern Ecological Framework Project
   o This project utilizes geographic information systems (GIS) for analysis ecologically significant areas in southeast states. The states include: Florida, Georgia, Alabama, Mississippi, South Carolina, North Carolina, Tennessee, and Kentucky.

The current efforts taking place throughout the southeast region are laying the foundation for the development of comprehensive Green Infrastructure programs that several cities in other parts of the United States have already implemented. We have chosen four leading cities to highlight the current state-of-the-art in Green Infrastructure programs. The four cities in particular that have established themselves as the front runners in developing successful Green Infrastructure programs are: Philadelphia, Chicago, Portland, and Seattle. The following pages consist of a review of activities and programs that have resulted in successful application of urban Green Infrastructure programs in each city.

It should be noted that there are differing definitions of Green Infrastructure or program emphases. Green Infrastructure can be thought of in two distinct ways: (1) as a set of links and nodes on a large scale (e.g. greenways connecting park areas), or (2) as a set of micro-control practices applicable to site design or redesign. The CSS area of Nashville focuses primarily on the second of these two understandings of Green Infrastructure. However, both approaches are applicable to the Nashville area.

Links

Alabama Community Planning
http://content.lib.auburn.edu/cdm4/browse.php?CISOROOT=/plans

Alabama Forestry Commission Urban and Community Forestry Financial Assistance Program
http://www.forestry.alabama.gov/urban_financial_assistance_progr.aspx?bv=4&s=1

Chattooga Watershed Green Infrastructure Plan
http://www.greeninfrastructure.net/content/project/chattooga-watershed-green-infrastructure-plan-ncscga

Georgia Master Gardener urban forestry training program
http://www.urbanforestrysouth.org/resources/presentations/urban-forestry-green-infrastructure/view

Georgia EPA Green Infrastructure Workshop
http://cfpub.epa.gov/npdes/newsemails.cfm?news_release_id=186

Georgia Green and Shovel Ready
http://www.environmentgeorgia.org/reports/energy/energy-program-reports/green-and-shovel-ready

Georgia Green Infrastructure Workshop
http://crd.dnr.state.ga.us/assets/documents/GIW06.pdf

North Carolina: EPA Green Infrastructure Case Study of University of North Carolina Chapel Hill
http://cfpub.epa.gov/npdes/greeninfrastructure/gicasestudies_specific.cfm?case_id=72

North Carolina House Bill 239 Reductions in Nutrient Loading
http://www.ncleg.net/Sessions/2009/Bills/House/PDF/H239v6.pdf

Southeastern Ecological Framework Project
http://www.geoplan.ufl.edu/epa/index.html

United States Geological Survey, Water Quality and Nonpoint Sources in Urban Watersheds: Key Findings from the First Decade of NAWQA Studies. National Water-Quality Assessment (NAWQA) Program
http://water.usgs.gov/nawqa/informing/urbanization.html

Philadelphia

Summary:
- One Inch Stormwater Standard
- Green Roof Tax Credits
- Green Review Process
- Fast-track Project Review
- Impervious Area-based Stormwater Fee
- Green Lot Retrofits

Source: Pennsylvania Horticultural Society

One Inch Capture

Philadelphia stormwater regulations require that the infiltration volume equal one inch of runoff from directly connected impervious areas for all new development and redevelopment projects within city limits.

Green Roof Tax Credits

The Philadelphia City Council, which has been working to address stormwater management costs, recently passed an ordinance in 2007 granting tax credits to businesses that install green roofs on their buildings. The maximum credit is $100,000 and applicable to up to twenty-five percent of costs incurred to construct the green roof. The credit is applied against the applicant's total business privilege tax liability for the year during which the project is completed. Since 2007 the City has been considering a mandate for the installation of green roofs covering 75% of roof space on buildings greater than 50,000 square feet. The current program has led to the establishment of significant numbers of green roofs including the PECO headquarters building on market and 23rd shown in the figure, which at 45,000 square feet, is the largest green roof in the state.

Green Review Process

Stormwater regulations passed in 2006 require all developers planning to use ground space of 15,000 square feet or more to submit stormwater plans early in the permitting process. Also occurring in 2006 was the partnering of the Department of Licenses and Inspections and the City Planning Commission, which has streamlined the permit review, inspection, and approval process. Additionally, any redevelopment projects reducing directly connected impervious area by at least 20% are exempt from standard Channel Protection and Flood Control Requirements. This exemption opportunity has not only led to an increased use of Green Infrastructure practices, but it has also led developers to build on infill sites instead of undisturbed natural land.

Fast-track Project Review

Projects with 95% or more of the impervious area disconnected from the combined or separate storm sewer can qualify for a fast track review process in which the stormwater management section of the project will be reviewed within five days of submittal. This option provides time and cost savings for the project and comes at low or no cost for the City.

Impervious Area-Based Stormwater Fee

Philadelphia has revised its stormwater billing system to account for the amount of impervious cover in the City belonging to non-metered customers such as parking lots and utility right-of-ways. The reallocation of stormwater charges from residential metered customers, who had previously been charged a flat rate, to large non-residential customers, is being implemented over a four year period beginning in 2009. This new fee structure is based on calculation of impervious cover, and more closely reflects the costs incurred by the City in managing stormwater from each property. Coupled with this change is an ordinance offering financial incentives to customers who install Green Infrastructure practices that reduce impervious cover. Further encouragement comes from the Philadelphia Water Department, providing assistance through site inspections and design recommendations.

Green Lot Retrofits

The conversion of vacant lots into Green Lots has allowed Philadelphia to employ Green Infrastructure while cleaning up abandoned, often debris-covered areas of the City. Green Lots add to the value of surrounding properties, while providing a social or recreation area for neighborhoods. These retrofits also help improve air quality, provides habitat for wildlife, recharges groundwater, and reduces the urban heat island effect. A maintenance program was established to keep the Green Lots clean and provide green jobs to community members.

Lessons Learned

Philadelphia demonstrates that there is more than one solution to managing stormwater. Land-based BMPs, infrastructure improvements, restoration, incentives, and regulations can be combined to develop a successful Green Infrastructure program. The Philadelphia Water Department spent about five years gathering information before making any significant policy changes. A successful program will take time to design, build, monitor, and test. Pilot programs are a key step on the way to city-wide implementation.

Another lesson to take from Philadelphia is to turn intangible benefits associated with green approaches into numbers and benefits that the community can grasp. Highlighting the improvements to property values, public parks, and aesthetics will assist in capturing the public's interest and support.

Links

City of Philadelphia Sustainable Zoning Ordinance Amendment – Sustainable Zoning
Bill No. 070366 – Introduced 2007
http://webapps.phila.gov/council/attachments/3670.pdf

Bill No. 080277 – Introduced 2008
http://webapps.phila.gov/council/attachments/4982.pdf

City of Philadelphia Stormwater Regulations
http://www.phillyriverinfo.org/Programs/SubprogramMain.aspx?Id=Regulations

EPA Green Infrastructure Case Studies: Philadelphia, PA
http://cfpub.epa.gov/npdes/greeninfrastructure/gicasestudies_specific.cfm?case_id=62

GreenPlan Philadelphia
http://www.greenplanphiladelphia.com/

Neukrug. H. A new course: From tunnels to trees.
http://www.planphilly.com/new-course-tunnels-trees

Ordinance Green Roof Tax Credit
http://webapps.phila.gov/council/attachments/3533.pdf

Philadelphia Going Green
http://www.phila.gov/green/

Philadelphia Water Department to Reallocate Stormwater Costs. Apartment Association of Greater Philadelphia
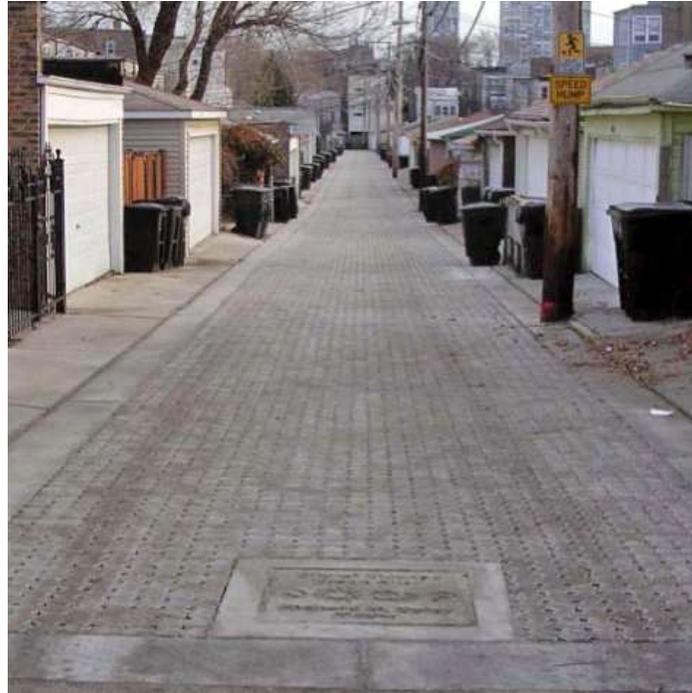http://www.aagp.com/Core/ContentManager/uploads/PDFs/PWDStormwater.pdf

WERF Livable Communities Case Study: Philadelphia, PA
http://www.werf.org/livablecommunities/studies_phil_pa.htm

Chicago

Summary:
- ⬥ Green Roof Density Bonus
- ⬥ Green Roof Improvement Fund
- ⬥ Green Alley Program
- ⬥ Green Roof Small Grant Program
- ⬥ Roof Solar Reflectance Standards

Source: Chicago Department of Transportation

Green Roof Density Bonus

The City of Chicago grants a floor area premium to developments that include public amenities such as green roofs. This allows the developer to increase the amount of square footage that can be developed while mitigating urban heat island effect and reducing stormwater runoff. In order to qualify, at least 50% of the roof area or a minimum of 2,000 square feet must be covered with vegetation.

Green Roof Improvement Fund (GRIF)

This is a one year pilot program launched in 2006 to assist building owners located within the Central Loop Tax Increment Financing (TIF) district with green roof retrofits through grant awards of up to $100,000. The Chicago City Council approved a total amount of $500,000 to start the GRIF TIF program, which would fund approximately 10 retrofits.

Green Alley Program

The City of Chicago has more than 1,900 miles of alleys that contributed to flooding of garages and basements. A pilot program, the Green Alley Program, was implemented by the Chicago Department of Transportation (DOT) in 2006 to manage stormwater and recharge groundwater with a goal of resurfacing 20 alleys per year with permeable pavers, permeable concrete, or permeable asphalt. The program has provided the added benefit of reducing urban heat island and smog levels. Between 2006 and 2008 there were a total 80 Green Alleys installed (example pictured on the previous page and at the right).

Alley with impermeable pavement and poor drainage.

Chicago residents are encouraged to green their own properties using guidance provided in the Chicago Green Alley Handbook: An Action Guide to Create a Greener, Environmentally Sustainable Chicago. Developed by the Chicago DOT, the handbook provides an overview of the Green Alley Program and describes the benefits of implementing green techniques on property adjacent to alleys. The handbook also includes illustrations on how to implement rain gardens, rain barrels, permeable

Alley incorporating green alley principles.

pavement, green roofs, and tree planting as well as the benefits of composting and recycling.

Green Roof Grants

The City of Chicago started a Green Roof Grants Program in 2005 that provides $5,000 grants to residential and small commercial buildings (< 10,000 square feet) meeting criteria based on location, visibility, and environmental benefit. The program is part of a larger effort by Mayor Richard Daley to make Chicago the greenest city in the United States. The initial number of grants was limited to 20 awards with a commitment to maintain the program for at least 5 years. A free informational seminar was held by the City during the first year of the program and 20 new green roof projects were implemented. Given the interest in the program, the number of grants was increased in 2006 and 40 Green Roof Grants were awarded. The City is not currently accepting grant applications.

Roof Solar Reflectance Standards

In 2001, as part of an effort to mitigate urban heat island, increase energy-efficiency, and reduce energy costs, the City of Chicago added a provision to their Energy Conservation Code requiring varying initial and three years post-installation solar reflectance values depending on roof slope. The current standards (roofs permitted on or after 1/1/09) are weaker than those established in the original provisions.

Lessons Learned

Mayor Richard Daley began greening the City of Chicago with a tree planting campaign in 1989, but the installation of the first municipal green roof in the US on the Chicago City Hall (pictured at the right) in 2001 is often cited as the beginning of the movement to make Chicago the greenest city in the country. The City has found success in implementation a multi-prong approach that includes not only leading by example, but also enforcement through regulation and public education. For example, the City held education seminars to encourage the private sector to install green roofs and survey residents on what incentive programs they would like to see implemented. This outreach effort included discussions to dispel common myths and misinformation about green roofs. Over the years Chicago has implemented short-term, manageable pilot programs and continued to establish partnerships and work with the public and private sector to work towards the common goal of a greener city.

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Portland

Summary:
- ⬥ Green Streets Policy
- ⬥ Downspout Disconnection Program and Subsidy
- ⬥ Rainwater Harvesting Codes
- ⬥ Clean River Rewards Incentive and Discount (CRID) Program
- ⬥ Ecoroof Grant Program
- ⬥ Green Roof FAR Bonus
- ⬥ Eco-logical Business Program

Source: Portland Bureau of Environmental Services

Green Streets Policy

In 2007, the City of Portland adopted a Green Street Policy that requires all city-funded development, redevelopment, or enhancement projects to manage stormwater runoff on-site at both the source and the surface (example pictured above). The use of vegetated practices that provide water quality benefit and infiltration capacity are encouraged. Projects that do not provide management are subject to an off-site project or off-site management fee. This policy takes advantage of transportation corridors to capture and treat stormwater runoff, create green space and pedestrian areas, and create attractive streetscapes that enhance neighborhood livability.

Downspout Disconnection Program and Subsidy

The City of Portland offers a reimbursement of $53 per disconnected downspout for property owners who make the change themselves. Property owners have the additional option of requesting that the City to do the disconnection work for free. Runoff from disconnected roof downspouts must be routed onto lawns and flowerbeds, or onsite stormwater BMPs such as drywells and soakage trenches. Portland's program is responsible for disconnecting over 50,000

downspouts and has removed an average of 1.5 billion gallons of stormwater per year from the combined sewer system.

Rainwater Harvesting Codes

Portland's Rainwater Harvesting One and Two Family Dwelling Specialty Code permits residential properties to collect and reuse rainwater for indoor non-potable purposes, such as toilet flushing. Commercial reuse systems (example pictured right) are considered on a case by case basis. Rainwater used only for outdoor irrigation is not covered by the code and is allowed on all sites. The code permits rainwater reuse for potable uses at family dwellings only through an appeals process.

Clean River Rewards Incentive and Discount (CRID) Program

The Clean River Rewards Incentive and Discount (CRID) Program provides property owners with the opportunity to earn a discount on their monthly stormwater utility charge by treating stormwater runoff onsite. Discounts are available to property owners based on the extent and effectiveness of on-site stormwater management practices that control flow rate, pollution and disposal. The CRID has a simplified discount program for residential properties based on roof runoff management, and a more complex commercial property program that requires management of runoff from all impervious areas.

Ecoroof Grant Program

The City of Portland offers grants of up to $5 per square foot for ecoroof projects within city limits (example pictured right). The roofs must manage stormwater and have a designated project manager. A committee has been established to review applications twice a year.

Floor Area Ratio (FAR) Bonus

Portland allows developers in the Central City Plan District to increase their building's Floor Area Ratio (FAR) when the design includes installation of an ecoroof. The bonus FAR is dependent on ratio of ecoroof coverage to the building footprint.

Eco-logical Business Program

Sponsored by the Pollution Prevention Outreach Team of Portland, this certification and recognition program highlights environmentally friendly businesses. Certification focuses on the collective impacts a business has on air, water, and waste. A business may request a certification visit, and, upon approval, receive a shop display package, press coverage, listing on the program web site, and promotion on the radio and at public events.

Lessons Learned

Portland's green streets program exemplifies how common road and right-of-way elements can be adapted and optimized to provide stormwater management in addition to other benefits. One of the biggest successes of the program was reevaluating common design features and recognizing that environmental performance can be improved by integrating stormwater management.

The Green Street team methodology that emerged drove Portland's pilot projects into a comprehensive, citywide multi-bureau program. Building on previous efforts by the Sustainable Infrastructure Committee and Portland Watershed Management Plan from 2005, City Council established a mandated policy, institutionalizing green street development. The result of this multi-agency approach is a sense of responsibility for the effort.

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Seattle

Summary:
- Natural Drainage Systems Approach
- Street Edge Alternatives (SEA) Pilot Program
- "Restore Our Waters" Strategy and Seattle Public Utilities (SPU) Comprehensive Drainage Plan
- Green Factor Program
- Triple Bottom Line Costing
- Drainage and Wastewater Fund
- Density Bonus Incentive
- Seattle Rain Barrels
- Aquatic Habitat Matching Grant
- Watershed Climate Action Grant
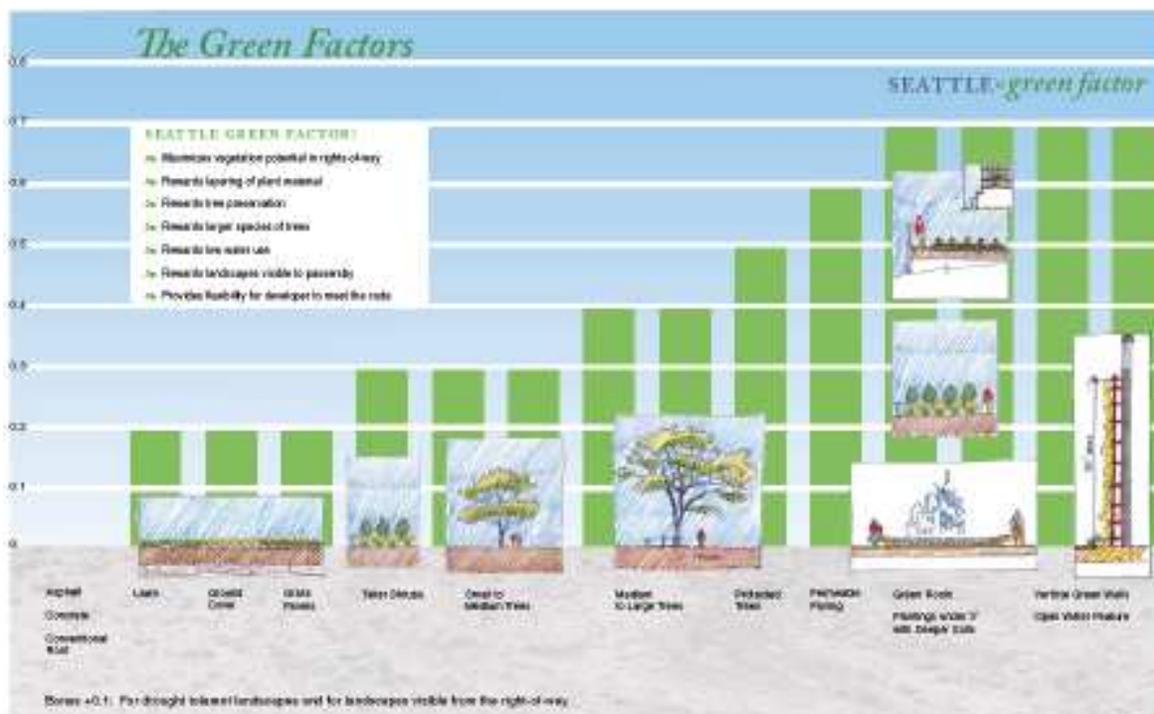
Source: Seattle Department of Planning and Development.

Natural Drainage Systems (NDS)

Natural Drainage Systems (NDS) is what Seattle has named its innovative Green Infrastructure approach to stormwater management. NDS uses alternative street designs and vegetated BMPs to reduce the volume and rate of stormwater runoff, striving to replicate pre-development site hydrologic function. In order to expedite the achievement of its water quality and flood mitigation goals, the City of Seattle has taken a proactive approach, retrofitting existing city streets using Low Impact Development techniques.

Street Edge Alternatives (SEA Street) Pilot Project

Seattle tested its NDS ideas through a demonstration project called Street Edge Alternatives (SEA Street – figure right), which was completed in the spring of 2001. The SEA Street project redesigned a residential city block. The street was narrowed, fitted with angled parking spaces, a sidewalk was added on one side, and paved area was reduced from 0.38 acre to 0.31 acre. To direct runoff into vegetated swales, a sinuous shape was given to the street. The project won a 2004 "Innovations in American Government Award" from Harvard University's Kennedy School of Government.

"Restore Our Waters" Strategy and SPU Comprehensive Drainage Plan

In September 2004, Seattle Mayor Greg Nickels introduced his "Restore Our Waters" (ROW) Strategy, a framework for coordinating and concentrating the City's efforts on rehabilitating local waterways. The Strategy requires updating the City's stormwater code to include options for Green Infrastructure alternatives to stormwater control. In response, Seattle Public Utilities drafted a new Comprehensive Drainage Plan, broadening the scope to include infrastructure, public safety, and aquatic resource protection.

Green Factor Program

The Green Factor Program was instituted in 2007, and requires 30% of a parcel in the Neighborhood Commercial Zone to be either vegetated or functionally equivalent to a vegetated area, as determined by completing a Green Factor Scorecard. This is the first such regulatory requirement in the US. The scoring system was created to promote the implementation of BMPs in areas visible to the public, such as along streets and sidewalks. Larger plants, permeable paving, vegetated walls, preservation of existing trees, and layering of vegetation are preferred measures, with bonuses provided for food cultivation, native and drought-tolerant plants, and rainwater harvesting. These aesthetically attractive elements will simultaneously improve air quality, create habitat for wildlife, and alleviate urban heat island effects. They also reduce stormwater runoff, protecting receiving waters and decreasing public infrastructure costs.

Triple Bottom Line Costing

SPU has adopted an innovative asset management methodology for selecting projects to build. The method uses a triple bottom line approach, considering the project's economic, social, and environmental costs and benefits. SPU is one of the first utilities in the United States to use this approach. The approach has been used by a number of utilities in Australia and Europe.

Drainage and Wastewater Fund

SPU has established a Drainage and Wastewater Fund, which is used to fund projects aimed at reducing water pollution associated with stormwater. The primary revenue source for stormwater projects is a drainage fee. Single family and duplex residential properties are charged a flat fee, while other property types are charged a fee based on property imperviousness. Properties harvesting rainwater are eligible for a 10% discount on their drainage fees. This fee provides a direct incentive for property owners to reduce site imperviousness and harvest rainwater for reuse while at the same time providing a revenue source for improvements to the stormwater system.

Density Bonus Incentive

The Density Bonus Incentive allows downtown commercial, residential and mixed-use developments which gain LEED Silver or higher certification to build to a greater height and/or floor area than would normally be permitted.

Seattle Rain Barrels

SPU partners with the Seattle Conservation Corps (SSC) to offer discounted rain barrels to SPU customers. The Corps assembles the rain barrels out of used shipping containers. For a fee the barrels can be delivered to a customer's home. A user manual is included with each barrel.

Aquatic Habitat Matching Grant

Individuals, business owners, non-profits, or community groups wanting to protect or restore Seattle's aquatic habitat may qualify for matching grants provided by Seattle Public Utilities. Grant awards begin at $2,000 per project, with $300,000 total awards available. Recipients are required to match the City's resources 100 percent. Projects considered must be within the city limits of Seattle and must aim to improve and/or restore aquatic habitat and/or ecological diversity, address water flow and/or quality, or improve/prevent impacts from Seattle's drainage systems.

Watershed Climate Action Grant

Established in 2008, the Watershed Climate Action Grant is a pilot grant program focused on restoring urban forests in the Puget Sound region. The grant provides volunteer groups with up to $1,000 in supplies such as plants and mulch, and up to two weeks in support, including the removal of invasive plants, tree planting, and aftercare.

Lessons Learned

SPU's Natural Drainage Systems program has received worldwide praise and attention. The program faced challenges and the City's emergency and transportation departments questioned the system's safety, integrity, and applicability. SPU worked with these departments to establish new road designs that met both the goals of the NDS program and the needs of emergency vehicles.

Community members were involved in all stages of NDS implementation, from planning and construction, to public education meetings on its importance and benefits. SPU highlighted the environmental benefits, cost savings, potential for increased property values, and aesthetic appeal of NDS, and helped ensure the program was well received by the public. Public acceptance has allowed SPU to solicit the assistance of homeowners in the upkeep of road-side vegetation, reducing the City's maintenance costs. Continued success of the program depends on the observation efforts of both community members and City maintenance crews to determine the effectiveness and potential life-span of the installations.

Links

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